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ORIGINAL ARTICLES.

I.—The Geological History of South Africa.[1]

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THE subject of this address is a brief account of the succession, thickness, and geological history of the South African, and more especially of the Transvaal, formations. The information necessary for such an account is of course very incomplete, but in broad outline the succession is now known, and some speculation as to the physical conditions that prevailed during the building up of the region may perhaps be permitted. I propose to deal with the period of the geological history of this country that came to an end with the close of Karroo times. The Karroo period ends with the Stormberg rocks (Rhætic), and since that time South Africa has, with the exception of a small coastal area, been a land surface, and the rocks have consequently been exposed uninterruptedly to the forces of denudation.

1. *Order of Superposition of the Stratified Rocks.*

As is well known, no determinable remains of organisms have been found in the Transvaal below the Karroo Beds, and none below the Bokkeveld Beds in the Cape Colony. In the absence of fossil evidence, the succession can only be established by a careful observation of the order of superposition and the lithological character of the strata. The succession has already to a great extent been determined by various workers, and the main dividing-lines placed at the great breaks or unconformities that have been found to exist. Thus we have, as natural dividing-lines, five great unconformities, namely, that below the Dwyka Conglomerate (which for future reference we will call Unconformity No. V), that below the Waterberg Sandstone (Unconformity No. IV), that below

[1] Presidential Address delivered by Dr. F. H. Hatch to the Geological Society of South Africa, 29th January, 1906.

the Black Reef Series (Unconformity No. III), that below the Ventersdorp System (Unconformity No. II), and that below the Witwatersrand System (Unconformity No. I). In regard to Unconformity No. V, we have the exception that in Southern Cape Colony the Table Mountain Sandstone, which some of us regard as the representative of the Waterberg Sandstone, is followed successively and in strict conformity by the Bokkeveld, the Witteberg, and the lower shales of the Dwyka Series.

The following order of superposition of the South African stratified rocks may be regarded as now fairly established :—

European Equivalents.	Southern Cape Colony.			Transvaal.	
Rhætic.	Karroo System.	Stormberg	Volcanic Group. Cave Sandstone. Red Beds. Molteno Beds.	Missing.	
		Beaufort		Missing.	
Permo-Carboniferous.	...	Ecca and Dwyka		= Ecca and Dwyka.	
					(No. V.)
	Cape System.	Witteberg		Missing.	
		Bokkeveld		Missing.	
		Table Mountain Sandstone		= Waterberg Sandstone.	
					(No. IV.)
Devonian.	... ...			Potchetstroom System.	Pretoria Beds. Dolomite Series. Black Reef Series.
					(No. III.)
				Ventersdorp System.	Boulder Beds, Volcanic Breccias, Klipriversberg Amygdaloid, etc. Elsburg Conglomerates.
					(No. II.)
				Witwatersrand System.	Upper Witwatersrand Beds. Lower Witwatersrand Beds.
					(No. I.)
Archæan.	Malmesbury Series			= Swaziland System.	

With the exception of one or two points, which I shall proceed to deal with, the above succession has found general acceptance. One of the points about which there is some considerable difference of opinion is as to how much or how little of the Karroo System above the Dwyka Conglomerate is represented in the Transvaal. The view originally put forward was that the coal-bearing beds of the Transvaal were a continuation of the Stormberg Beds of the Cape. This was adopted by Molengraaff in his first geological reports; but later, in the course of a discussion as to the age of the coal beds which took place in the Society some two years ago, he came to the conclusion that our coal beds corresponded to the Beaufort Beds.[1] Since then the conviction has grown amongst

[1] Molengraaff, Discussion on Dr. Corstorphine's paper "The Age of the Central South African Coalfield": Trans. Geol. Soc. S. Afr., vol. vi (1903), p. 45.

some of us that the Transvaal coal horizon corresponds rather to the Ecca Beds.

The present Director of the Transvaal Survey, however, has adopted Dr. Molengraaff's view that the Ecca Series is not represented at Vereeniging, the Dwyka Conglomerate being immediately followed by the Beaufort Series or Upper Karroo, as he terms it.[1] But, as militating against this view, I would point out that the Transvaal Coal-measures, while containing plant remains that are common both to the Ecca and to the Beaufort Series (such as *Glossopteris, Schizoneura,* and *Phyllotheca*), have also yielded abundant specimens of two species which at the Cape have only been found in the Ecca Beds. I refer to *Noeggerathiopsis Hislopi*, which occurs both in the Middelburg Coalfield (Boschfontein)[2] and at Vereeniging, and to *Gangamopteris cyclopteroides*, which occurs at Vereeniging.[3] *Cardiocarpus*,[4] which is associated with *Gangamopteris* and *Glossopteris* in Ecca Sandstone near Worcester, also occurs at Vereeniging. Moreover, to regard the Vereeniging Beds as of Beaufort (Upper Karroo of the Survey) age must involve the assumption of a considerable unconformity between the Dwyka Conglomerate and these beds, unless indeed we are to believe that the deposition of the glacial conglomerate took place at a much later date in the Transvaal than in the Cape Colony.

A minor matter to which the attention of the Survey might be drawn is the nomenclature to be adopted for the Karroo System, for if the coal sandstones are to be regarded as corresponding to the Beaufort Beds of the Cape, then it will be much preferable to retain the name of Middle Karroo Series for them, since the term Upper Karroo is applied only to the Stormberg Beds at the Cape.

Another difference of opinion between the Survey and some of us exists as to the unconformity beneath the Witwatersrand Beds; and whether the latter form an independent system, or are but a portion of a more comprehensive system in which the granite is intrusive. The Director of the Survey is apparently not prepared at present to admit that there is in the Transvaal an older system than the Witwatersrand. He is not satisfied with the evidence that has been advanced that the Mont Maré schists are older than the Witwatersrand, nor that the Witwatersrand Beds are younger than the granite on which they rest.[5] In taking up this position he ignores the evidence as to the relative age of the granite and the Witwatersrand Beds furnished by Dr. Corstorphine[6] and the late

[1] Kynaston, "Geology of the Transvaal and Orange River Colony": Science in South Africa (1905), p. 298.

[2] Seward: Q.J.G.S., 1897, p. 322.

[3] Feistmantel, "Uebersichtliche Darstellung der geologisch-palæontologischen Verhältnisse Süd-afrikas": Abhandlungen d. königl. böhm. Ges. d. Wiss., Folge vii, Band 3; Prague, 1889.

[4] Seward: Q.J.G.S., 1897, p. 322.

[5] Transvaal Geological Survey Report, 1904, p. 18.

[6] G. S. Corstorphine, "The Geological Relation of the Old Granite to the Witwatersrand Series": Trans. Geol. Soc. S. Afr., vol. vii (1904), pp. 9–12.

Mr. Dörffel.[1] But what is the nature of the evidence that he would deem satisfactory to establish the relation of the Witwatersrand Beds to the granite? They are seen in contact at numerous places, but nowhere is the latter found penetrating or sending off apophyses into the former. Neither do the sediments show anywhere any sign of contact metamorphism. On the contrary, they appear to have been accumulated on an ancient granite floor. If the granite were later than and intrusive into the Witwatersrand Beds, surely some evidence of this would be forthcoming. It is true that Mr. Kynaston does not deny the possibility of an unconformable relation, but he records the evidence as insufficient.

Now this is a question which affects the mapping of thousands of square miles of country; it is besides important to the public from a mining point of view. I will give an instance — bore-holes put down by exploration companies through the overlying covering of Karroo rocks or Dolomite are invariably stopped if they should reach the Granite. Is the doubt as to the usually accepted relation of the Granite to the Witwatersrand Beds so strong in Mr. Kynaston's mind that he would advise the continuation of such boreholes? We unfortunate geologists and mining engineers, who have to take practical views of such matters, are not allowed the luxury of academic doubt. Further, the important question is involved as to the relation of the Witwatersrand Banket to the conglomerates and quartzites that occur in association with schistose rocks in the Barberton and Pietersburg districts, and in Swaziland and Mashonaland, a question which has recently been much discussed, owing to the prominence given to the so-called banket occurrence at Lomagunda in Rhodesia, and its correlation with the Witwatersrand rock.[2] I maintain that instead of shelving questions like these, the Survey should investigate the facts, and establish definitely the relation of the Witwatersrand Beds to the Old Granite, and the existence or non-existence of an older system of sedimentary rocks. These are questions of vast importance to the mining industry, and call for as early a settlement as possible.

While the maps produced by the Survey are a fit subject for congratulation there is room for a difference of opinion as to the line on which the survey work should be carried out. Personally I am of the opinion that in the present stage of the development of the country the most good would be done, not by giving us detailed maps (however excellent in themselves) of outside districts, but by settling the large questions which its Director holds still require solution.

While on the subject of the Survey I will touch on another question, of the importance of which Mr. Kynaston is as fully cognisant as we are. The maps issued by the Survey since its reorganisation in 1902 cover an area of about 4,100 square miles.

[1] D. Dörffel, "Note on the Geological Position of the Basement Granite": Trans. Geol. Soc. S. Afr., vol. vi (1903), pp. 104–105.

[2] F. P. Mennell, "The Banket Formation of Rhodesia": Trans. Geol. Soc. S. Afr., vol. viii (1905), p. 82.

This is a very creditable performance considering the smallness of the staff. But a simple computation will show that at this rate of progress some 30 years will be required to finish the work unless the staff be augmented. The importance of rapidly completing the geological survey of a country, dependent as this is for its future welfare on the development of its mineral resources, cannot be too strongly impressed on the authorities; and to accomplish it the staff must be largely increased. I am glad that we can welcome an additional field geologist in the person of Dr. W. A. Humphrey, who has had part of his training in South Africa, and we may trust that this is an augury of the Government's recognition of the importance of the work, and of its intention to carry it out with the least possible delay.

I will pass on now to a consideration of the data available for deducing the thickness of the South African formations.

2. *Thickness of the Strata.*

Since we know neither the base nor the summit of the Swaziland system no estimate can be made of the thickness of these ancient rocks, which are partly of sedimentary, partly of igneous origin, but have in both cases been profoundly modified. There can be no doubt, however, that they are very thick, and that an immense quantity of material has been removed by erosion since their first upheaval. Recently, in a paper read before this Society, Dr. Voit[1] has expressed the opinion that certain banded gneisses of the Northern Transvaal should be separated from the Swaziland system as an older fundamental gneiss, corresponding, say, for instance, to the Laurentian rocks of Canada and the Lewisian gneiss of Scotland. As, however, he describes no section from which the relation of these gneisses to the remainder of the Swaziland system can be inferred, and since it is by no means certain that these gneisses are anything else than a sheared or metamorphic portion of the granite, which in other places is found intrusive in the Swaziland Beds, it must be premature in the present state of our knowledge to attempt any such subdivision.

With regard to the Witwatersrand System, the shales and quartzites of the lower division have on the Rand a thickness of 12,000 feet; the upper division, if we exclude the Elsburg Series, about 7,000 feet; in all about 19,000 feet. The necessity of separating the Elsburg Series from the Witwatersrand Beds, which was advocated by Dr. Corstorphine and myself in a paper on the Geology of the Bezuidenhout Valley, read before this Society, is again shown by fresh evidence from the Klerksdorp district, which will be made the subject of a paper by Mr. Torissen. This series of conglomerates and quartzites has on the Rand a thickness of from 3,000 to 4,000 feet. I include it with the Ventersdorp System.

The thickness of the latter system, which includes boulder beds, coarse conglomerates, volcanic breccias and lavas, is very difficult

[1] F. W. Voit, "Gneiss Formation on the Limpopo": Trans. Geol. Soc. S. Afr., vol. viii (1905).

to compute. South of the Rand the Klipriversberg Amygdaloid has a thickness of at least 4,000 feet, and adding this to the thickness of the Elsburg Series, we get a total of 7,000 to 8,000 feet for the thickness of the Ventersdorp System as developed on the Rand.[1]

The Potchefstroom System presents difficulties of another kind, owing to the very variable thickness of its lower members, the Black Reef and the Dolomite Series. In the Pretoria and Witwatersrand districts the Black Reef Series is under 100 feet, even sinking to as little as 10 to 20 feet, as has been proved by boreholes on the East Rand[2]; whereas at Pilgrims' Rest Mr. Thord-Gray[3] has recently estimated its thickness at 1,800 feet, while Mr. Sawyer[4] gives it as 1,200 feet at Chunies Poort. The Dolomite Series has been estimated in the Pretoria district at 5,000 feet by Molengraaff,[5] although Mr. Kynaston considers it probable that its thickness does not exceed 3,000 feet in that district. In the Makapan Mountains Molengraaff puts it at 4,000 feet, near Godwan at 1,650 feet, in the vicinity of Lydenburg at 2,600 feet, and south of the Witwatersrand at 2,600 feet. Mr. Thord-Gray gives its thickness at Elandsfontein in the Lydenburg district as 3,000 feet, while Mr. Holmes informs me that from careful measurements he has made in the Marico district, where the series exists in very regular order in the Dwarsberg, he estimates the thickness of the Dolomite at as much as 7,500 feet, the Black Reef Series being very thin there, not more than 75 feet. Taking the thicknesses given above, it would appear as if where the basal quartzites are largely developed, as in the Lydenburg district, the Dolomite suffers a corresponding diminution, and where the Dolomite is thick the Black Reef is poorly developed. Together, the maximum thickness of the two formations probably does not exceed 8,000 feet. In Griqualand West Messrs. Rogers and Schwarz have found the limestone series, "measured from the quartzites, below which no limestone is seen, to the lowest jaspers or magnetite quartzites of the Griquatown Beds (Pretoria Series)," to have a thickness of 5,000 feet, while the underlying quartzite (Black Reef Series) varies from 200 to 2,000 feet.[6]

The Pretoria Series is estimated by the Transvaal Geological Survey to have a thickness of not less than 10,000 feet.[7] Mr. Holmes has measured this series in the Dwarsberg (Lotteringskop), and

[1] F. H. Hatch & G. S. Corstorphine, "The Geology of the Bezuidenhout Valley and the District East of Johannesburg": Trans. Geol. Soc. S. Afr., vol. vii (1904), pp. 97–109.

[2] F. H. Hatch, "The Extension of the Witwatersrand Beds eastward under the Dolomite and the Ecca Series of the Southern Transvaal": Trans. Geol. Soc. S. Afr., vol. vii (1904), p. 63.

[3] I. Thord-Gray, "Notes on the Geology of the Lydenburg Goldfields": Trans. Geol. Soc. S. Afr., vol. viii (1905), p. 66.

[4] A. R. Sawyer, "The Geology of the Transvaal": North of England Inst. Min. Engineers, 1905.

[5] G. A. F. Molengraaff, "Geology of the Transvaal": Johannesburg, 1904.

[6] A. W. Rogers & E. H. L. Schwarz, "Geology of the Orange River Valley in the Hopetown and Prieska Districts": Ann. Rep. Geol. Comm. Cape Colony, 1899, p. 80.

[7] Transvaal Geol. Surv. Rep., 1903, p. 40.

informs me that his figures work out to 9,900 feet, which is in very close agreement with the estimate of the Survey. We have, therefore, a maximum aggregate thickness for the three members of the Potchefstroom System of about 18,000 feet.

The thickness of the Waterberg Sandstone has not been measured in any place where there is anything approaching a complete section. The lower beds, however, have been carefully examined by Mr. Mellor in the Rhenosterkop area, and were found by him to have a thickness of 3,150 feet.[1] The Table Mountain Sandstone, which appears to be the Cape representative of the Waterberg,[2] is estimated by the Cape Survey to have a thickness of 5,000 feet, and there can be very little doubt that the Waterberg formation is at least as thick.

The Bokkeveld Beds, which succeed the Table Mountain Sandstone at the Cape, are estimated by the Cape Survey at 2,500 feet, and the same thickness is given to the Witteberg Beds, making a total thickness for the Cape System of 10,000 feet. The Bokkeveld and Witteberg Series are, however, absent in the Transvaal.

According to Mr. Rogers,[3] the Karroo System has a thickness of 18,000 feet, of which 4,900 feet is apportioned to the Dwyka and Ecca Series, 5,000 feet to the Beaufort Beds, and 8,200 feet to the Stormberg, 4,000 feet of the latter being occupied by the volcanic group which forms the summit of the system.

Summarising, we have the following maximum thickness for the South African stratified rocks:—

Karroo System	18,000	feet.
Cape System (in which is included the Waterberg formations, as correlative with the Table Mountain Sandstone)	10,000	,,
Potchefstroom System ... ... about	18,000	,,
Ventersdorp System ... ... about	8,000	,,
Witwatersrand System	19,000	,,

Excluding the Karroo Beds, there remain some 55,000 feet of beds (say 10 miles) lying below the base of that system and above the Swaziland Beds, or, in other words, below the Permo-Carboniferous of Europe. When we take into consideration the gaps represented by four great unconformities, we see that the 'geological column' must necessarily be much greater than this total, since no allowance is made for the losses due to denudation. It probably embraces the period of time covered by the Devonian, Silurian, Ordovician, and Cambrian Systems of the European classification.

Unfortunately, no correlation with the European formations is at present possible, on account of the complete absence of fossils in all the South African formations below the Bokkeveld (Devonian) Beds.[4] But we need not despair of finding organic remains in some

[1] Transvaal Geol. Surv. Rep., 1904.

[2] F. H. Hatch & G. S. Corstorphine: "The Geology of South Africa," p. 309; London, 1905.

[3] A. W. Rogers: "The Geology of Cape Colony," p. 147; London, 1905.

[4] Quite recently some lamellibranch remains have been found by the Cape Survey in the Table Mountain Sandstone, but have not yet been determined.

of these formations, when we remember the patient search that has been necessary in Europe in order to obtain fossil evidence for the age of important formations. Rogers [1] instances the work done in the north of Devonshire by two generations of geologists before the Morte slates were found to be fossiliferous. We may still hope that some of our more promising shales and limestones will yet yield palæontological evidence which will enable them to be correlated with the classic systems of Europe.

(*To be concluded in our next number.*)

II.—The Physical History of the Great Pleistocene Lake of Portugal.[2]

By Professor Edward Hull, LL.D., F.R.S., F.G.S.

A RECENT visit to Portugal has given me an opportunity of seeing the geological features of the neighbourhood of Lisbon and the Lower Tagus; and though of a somewhat cursory nature I venture to bring them before the Society, being supplemented by reference to the investigations of previous observers, and a study of the excellent geological maps which are in the library of this Society. I make no pretension to be an original explorer, but I hope to be able to show that there is a very interesting physical history, not hitherto written so far as I am able to discover, bringing down the account of the changes which have taken place from the Cretaceous period to the Recent, or Quaternary, epoch.

In addition to my own observations I have relied for the necessary data for this paper on the geological maps of Portugal,[3] together with the papers of the late Mr. Daniel Sharpe [4] and of Mr. Smith [5] of Jordan Hill, which sufficiently put us in possession of the materials for an historical sketch of the remarkable physical changes which the Iberian Peninsula has undergone, at least along its western margin, in Tertiary and still more recent times.

Geological Formations.

The formations bordering the lower banks of the Tagus near Lisbon are arranged by Sharpe in the following order of succession:—

Mr. D. Sharpe's Classification.

1. Upper Tertiary Sands, etc.
2. Almada Beds (Marine).
3. Lower Tertiary Conglomerate.
4. Hippurite Limestone (Cretaceous).

[1] "Geology of Cape Colony," p. 114; London, 1905.

[2] Read before the Geological Society, December 6th, 1905.

[3] "Carta Geologica de Portugal," ed. by Carlos Riberio & J. F. N. Delgado (1876); "Mapa Geologico de España y Portugal," by D. F. de Botella (1879).

[4] "On the Geology of Lisbon": Trans. Geol. Soc., ser. II (1839), and Q.J.G.S., vol. vi, p. 134 (1850).

[5] "On the Age of the Tertiary Beds of the Tagus": Q.J.G.S., vol. iii, p. 410 (1847).

In the *Legenda* of the Geological Map of Portugal the succession does not materially differ from the above, and is as follows :—

Terciario	Moderno e quaternario (alluvial).
	Lacustre superior.
	Marino (Almada Beds).
	Lacustre inferior.
Cretaceo	Superior (Hippurite Limestone).
	Inferior.

Description.

The Upper Tertiary (Lacustre superior) consists of fine white, yellow, and red sands, with thin layers of rolled pebbles, nearly horizontal and 100 feet in thickness, resting on 150 feet of coarse ferruginous sands and gravel; no organic remains have been observed in these beds; but at a locality 15 miles from Verdelha, on the north bank of the Tagus, the hills rising about 200 feet above the sea consist of brown marl and soft rubbly limestone containing *Lymnæa longiscata* (Sow.), and have been traced from Cartaxo to Santarem. These are probably the uppermost beds of the lacustrine series, and overlie the sands and gravels previously described.

At Villa Franca a bed of marl occurs 50 feet above the Tagus with *Lutraria compressa*, and near Villa Nova da Rainha the same shell occurs with *Cardium edule*, both now living in the estuary of the Tagus near Lisbon; so that, as Sharpe observes, it is evident that this part of the country has been upheaved at least 50 feet within a comparatively recent period.[1] The occurrence of these shells indicates, as it seems to the writer, a local intrusion of the sea-waters at an early stage of the "Lacustrine" period.

The Almada Beds (Miocene).

These beds are so named by Sharpe from the promontory on the south bank of the Tagus, opposite the city of Lisbon, where they are well shown in the sea cliff. They consist of marls and limestones rich in marine fossils, and are considered by Smith to be of Older Miocene age. Of the 124 species determined, 20 are new and peculiar, and are figured and described by G. B. Sowerby,[2] 51 occur in the Older Miocene beds of Bordeaux, 17 in the Falunes of Touraine, 15 in the sub-Apennine beds, 8 in the Eocene of the London and Paris Basins, and 35 are recent. Their claim to be referable to the Miocene stage is thus clearly established. At Lisbon they rest unconformably on the Cretaceous Limestone.[3]

Pliocene Beds not represented.

It will be observed that the "Almada Beds" of Miocene age are immediately succeeded by those denoted on the Geological Map of Portugal as "Lacustre superior," and by Sharpe called "Upper Tertiary Sands, etc." The relative position of these sands to the

[1] Sharpe, ibid., p. 138.
[2] James Smith, supra cit., pp. 410–423.
[3] The Almada Beds rest on the sands and gravels called "Lacustre inferior," but as they are unfossiliferous their geological age is obscure or unknown.

underlying "Almada Beds" in the neighbourhood of Lisbon is very clearly shown in the sections accompanying Mr. Sharpe's paper; for, while the Almada Beds are inclined at angles varying from 10° to 15°, the Upper Sands are well-nigh horizontal. In addition to this the Almada Beds have been faulted and denuded, and subjected to disturbances which do not affect the Upper Lacustrine Sands. All these phenomena go to indicate absolute disconnection between the two formations, a disconnection which in time would in other districts have been filled up by the Pliocene beds, but which are here altogether absent from their place in the geological series. The cause of this *lacuna* I hope to be able to explain further on.

The Sub-Oceanic Extension of the Tagus.

When a few years since I was endeavouring to determine by the aid of the soundings on the Admiralty Charts the physical features of the land areas now covered by the waters of the Eastern Atlantic, I was enabled to show that the principal rivers of Western Europe, and partly of Africa, were continued across the continental platform to great depths and various distances under the ocean from their present outlets. Amongst these the sub-oceanic Tagus was one of the best developed, and can be well delineated owing to the large number of soundings off the coast of Portugal. The isobathic contours are perfectly clear, as will be seen from the photographic slides, together with those of the Adour in the north of Spain and the Congo on the coast of Africa.[1] In reference to the sub-oceanic cañon of the Adour, I may mention that Dr. Nansen, who in northern latitudes has studied these physical features, has stated that it is impossible to suppose that it can be anything else than a drowned river valley.[2]

I do not intend to go farther into the question of these submerged valleys, except as they are connected with the geological history of the Tagus valley. Their existence is clearly due to river erosion, inasmuch as they could not have been formed under the ocean-waters themselves. The question we are here concerned with is the determination of the geological period of their formation. The conditions must have been those of great land elevation affecting the ocean-bed and adjoining lands. That they are not of great geological antiquity is shown by the fact that the rivers with which they were continuous are geologically modern, more modern indeed than the Chalk, and, in this district, than the Miocene, which, as shown above, is a marine deposit.

Pliocene Elevation.

It is to the Pliocene and post-Pliocene epochs that we must therefore refer that great land-uprise which would be necessary for the erosion

[1] These photographic pictures were then exhibited, but have already been described in the Trans. Viet. Inst., vols. xxxi and xxxii.

[2] Nansen, "Bathymetrical Features of the North Polar Seas, etc.," p. 95 (1893–5).

of these river-valleys, and owing to which there was no deposition of strata under the ocean. To this cause I venture to attribute the absence of representatives of the Pliocene formation in Portugal; as, indeed, is the case with other parts of the Continent and the western areas of the British Isles.

From the above considerations it will be seen that between the "Upper Tertiary Sands" of Sharpe (or the "Lacustre superior" of the Geological Survey) and the marine "Almada Beds" there is no physical connection. As regards periods of formation, they are separated by the whole of the Pliocene and probably post-Pliocene periods, as already stated. It is therefore necessary to revise the classification of the post-Cretaceous series of the authors above quoted, and I therefore venture to substitute for these the following arrangement of the beds.

Revised Classification.

Quaternary	1. Recent and Quaternary.	Alluvia of the valley and estuary of the Tagus.
	2. Lacustrine.	Marls with *Lymnæa*, sands and gravel.
	3. Post-Pliocene and Pliocene.	Not represented unless by some land-glacial beds due to elevation.
Tertiary	4. Miocene.	Almada Beds, calcareous marls and limestones with marine fossils.
	5. Eocene (?).	Unfossiliferous sands and gravels (Lacustre inferior) of doubtful age.
Cretaceous	6. Upper.	Hippurite Limestone.

Personal.

When observing the sections of strata, along the line of the railway for several miles between Carlaxo and Abrantes, consisting of white, yellow, and red laminated sands, with lines of rolled pebbles, horizontally stratified, and extending to a height of 150 to 200 feet above the river, it became evident that these beds could not have been deposited by the river itself; and I arrived at the conclusion that they must have formed the bed of an extensive lake. I was therefore anxious to ascertain whether my conclusion was borne out by the Geological Survey Map of Portugal. It was therefore with great satisfaction that on consulting the maps I found that these beds were included under the term "Lacustre superior." They are specially coloured, and, according to Sharpe, cover an area of "2,000 to 3,000 square miles."[1] On crossing the Tagus at Praia we find the country formed of extensive plains of gravel, from which at Das Vargans and Cunheira the bed-rock of granite emerges and the gravel and sand cease; this limit of the lacustrine beds probably corresponds very nearly with that of the original waters of the lake itself. To this point of the limit of the lake it is now necessary to direct our attention for a brief space.

[1] Supra cit., p. 138.

The Limits of the Pleistocene Lake of Portugal.

In dealing with this question I have to be guided by the Geological Map of Portugal, on which is represented the area of the "Lacustre superior" beds by a light-yellowish tint. Thus guided, the margin of the lake stretched along the banks of the Tagus from Cartaxo to Abrantes; then turning southwards it stretched to Alvallade, and thence to the Atlantic coast and the mouth of the Tagus. Over this area the lacustrine beds rest directly on the granitic rocks, or on the supposed "Lower Lacustrine" beds (Lacustre inferior), the Miocene beds being absent; they have therefore no connection with the upper lacustrine deposits with which we are dealing. The margin of these deposits is, according to the map, much indented along the river-valleys flowing towards the west, and showing that they have been considerably denuded during the rising of the land which took place subsequently, and to which is owing the drainage of the lake itself.

During the period of depression in which the waters of the lake accumulated, it would appear that the general level of its bed was nearly that of the outer sea, and that the sea-waters gained access occasionally during the earlier stage of its formation, owing to which (as already stated) some marine molluscs gained access. The magnificent harbour of Lisbon doubtless formed a portion of the lake, and the narrow channel by which it is connected with the ocean may be regarded as the unsubmerged portion of the great sub-oceanic cañon which carried the waters for about fifty miles beyond its present outlet. On the final uprise of the land to its present level the channel of the river was deepened, and the waters of the lake were drained off; and thus the great river which filled the basin afterwards became the agent by which it was ultimately drained.

Such appears to have been the physical changes coming down into recent times which have brought about the present conditions of land and sea in the western part of the Iberian Peninsula.

Glacial Conditions in Pliocene Times in Portugal.

In connection with the Pliocene elevation here postulated, it is interesting to observe that it was concurrent with extensive glacial conditions in the western portion of the Iberian Peninsula. It has long been known that the glaciers of the Pyrenees, like those of the Alps, extended far beyond their present limits in the Glacial period, but it is not so generally known that Portugal was the seat of extensive glacial conditions. This, however, was the case; and according to the views of Sgr. Delgado, the Director of the Portuguese Geological Survey, than whom there is no higher authority, these conditions commenced with the Pliocene epoch, gradually giving way to one of progressive refrigeration of the climate, accompanied by an invasion of glacial ice descending from the mountain chain of the Serra d'Estrella. This chain, commencing

at Garda, ranges in a south-west direction through the centre of Portugal, attaining a height of 6,539 feet, and was, in all probability, the most important axis of glacial dispersion during the post-Pliocene period. Of the great extent of glacier-ice both to the north of the Serra, where it invaded the affluents of the Mondégo, as well as the regions to the south towards the valley of the Tagus, there can be no doubt since the publication of M. Delgado's elaborate memoir,[1] following on that of his late colleague, M. Frederico A. de Vasconcellos,[2] both beautifully illustrated by photographic plates, recalling all the familiar phenomena of mountainous regions from which the glaciers have disappeared. According to Delgado there were two glacial stages separated by an interglacial one ("La phase interglaciaire"), corresponding to those which, in company with some British geologists, I have long held as having occurred in the British Isles. The most important point to be noticed is the occurrence of these glacial phenomena at an epoch corresponding to that of the elevation of the land and the erosion of the now submerged valley of the Tagus. If there are any geologists who regard this concurrence of events as accidental I am unable to agree with them. To the mind of myself, and a goodly number of other physicists both in Britain and America,[3] the glacial conditions are the direct result of the land elevation, for the simple reason that altitude above the sea-level is the governing factor, though not the only one, in the occurrence of warm and cold temperatures in all parts of the globe, even in equatorial regions. If the surface of Portugal was sufficiently elevated to allow of the erosion of the Tagus out to a distance from the coast of 55 miles, and to a depth of over 7,000 feet from the surface of the ocean,[4] we have the measure of the elevation of the land at the Glacial period. Adding, therefore, the depth of the submerged cañon (7,200 feet) to the present elevation of the Serra d'Estrella (6,539 feet), we have as the result a mountain 13,739 feet high, a height sufficient, notwithstanding its latitude, to give rise to a system of glacial dispersion and erosion, to some degree, comparable with that of the Alps at the present day. I now feel satisfied that, on observing the forms of the granite masses as they emerged from beneath the lacustrine gravels towards the Portuguese frontier, I was not mistaken in recognising them as ice-worn surfaces.

[1] "Note sur l'Existence d'anciens Glaciers dans la Vallée du Mondego," par J. F. Nery Delgado, extr. des Communicadões da Direc. dos Tratalhos Geologicos, tome iii (1895).

[2] Ibid., tomè i, p. 189 (1887).

[3] See Professor J. W. Spencer on "Professor Hull's Sub-oceanic Terraces, etc.," a review, *American Geologist*, vol. xxxv (March, 1905).

[4] Trans. Vict. Inst., vol. xxxi, p. 284, footnote.

III.—On a Collection of Fossil Corals from Eastern Egypt, Abu Roash, and Sinai.

By J. W. Gregory, D.Sc., F.R.S., F.G.S.,
Professor of Geology, Glasgow University.

(PLATES VI and VII.[1])

(*Concluded from the February Number, p. 58.*)

III. PLEISTOCENE.

SYMPHYLLIA, Edwards & Haime, 1848.

Symphyllia erythracea (Klunz.), 1879.

Isophyllia erythracea, Klunzinger, 1879: Korallth. roth. Meer., pt. iii, p. 10, pl. i, fig. 10; pl. ix, fig. 9.
Symphyllia erythracea, Gregory, 1898, Egypt. Foss. Madreporaria: Geol. Mag., Dec. IV, Vol. V, p. 242.

Distribution.—Recent: Red Sea (Klunzinger). Pleistocene, fossil: ? Jebel Zeit (Gregory, 1898); also Old Beach, Camp 7; Wadi Barud, Eastern Egypt. No. J 1789.

STYLOPHORA, Schweigger, 1819.

1. Stylophora elongata (Lamarck), 1816.

Porites elongata, Lamarck, 1816: Hist. nat. Anim. sans Vert., vol. ii, p. 271.
Stylophora elongata, Klunzinger, 1879: Korallenth. roth. Meer., pt. ii, p. 64, pl. vii, fig. 14; pl. viii, fig. 19.

Six fragments and a slide cut from one of them (No. J 2153), collected by Mr. Barron on the coastal plain between Ras Jemsa and Jebel Zeit, agree in all characters with this species, which is clearly very closely allied to *S. pistillata* (Esper), the common Red Sea form.

Eight worn fragments, J 2186, from the raised beach, east of Jebel Esh, belong to the same species.

2. Stylophora cf. palmata (Blainville), 1830.

Siderapora palmata, Blainville, 1830: Dict. Sci. nat., vol. lx, p. 360.
Stylophora palmata, Edwards & Haime, 1850: Ann. Sci. nat., ser. iii, vol. xiii, p. 103.

Distribution.—Recent: Red Sea and Indian Ocean. Fossil, Pleistocene: 380 feet above sea-level, near Camp 8 in Wadi Shigeli.

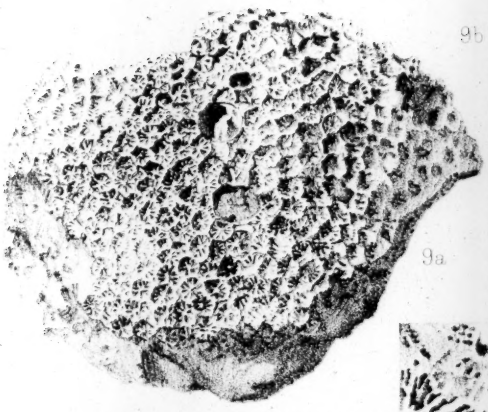
There are two limestone specimens, which bear surface casts of a *Stylophora*, which are probably *S. palmata*, but they are not sufficiently well preserved for certain identification. They were collected by Mr. Barron, 380 feet above the sea, near Camp 7 in Wadi Abu Shigeli. J 1667.

CŒLORIA, Edwards & Haime, 1848.

Cœloria lamellina (Ehrenberg), 1834.

Platygyra lamellina, Ehrenberg, 1834, Beit. Coralleuth. roth. Meer.: Abh. k. Akad. Wiss. Berlin für 1832, p. 323.
Cœloria lamellina, Edwards & Haime, 1851: Pol. foss. Terr. palæoz., p. 93; 1857, Hist. nat. Cor., vol. ii, p. 415.

[1] [By an error of the binder, *both* Plates VI and VII appeared in the February Number with the first part of this paper.—Edit. Geol. Mag.]



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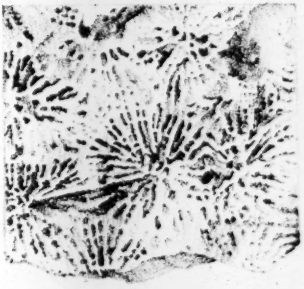

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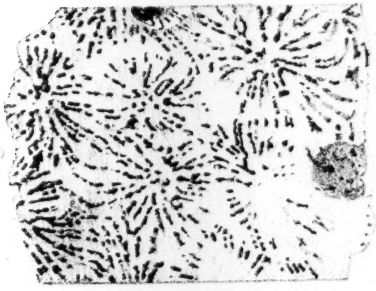

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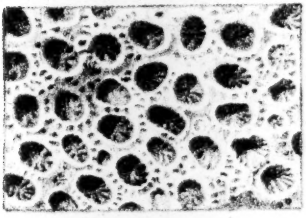

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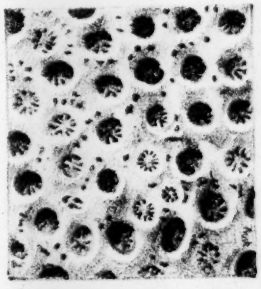

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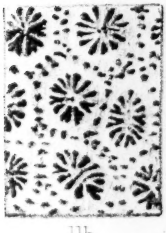

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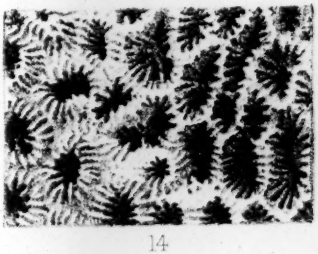


14

Drake del. et lith.

West, Newman imp.

Fossil Corals from Eastern Egypt &c.
Figs 9–11 Miocene. Figs 12–14 Pleistocene.

Cœloria ehrenbergiana, Edwards & Haime, 1849: Ann. Sci. nat., ser. III, vol. xi, p. 296.
Platygyra labyrinthica, var. *leptochila*, Ehrenberg, 1834: op. cit., p. 323.
Cœloria labyrinthiformis, Haeckel, 1876: Arab. Korall., pl. ii, fig. 4.
Cœloria forskaliana, Edwards & Haime, 1849: op. cit., p. 296.
Cœloria forskaliana, Edwards & Haime, 1851: op. cit., p. 93; 1857, op. cit., p. 414.
Cœloria lottæ, Edwards & Haime, 1849: op. cit., p. 295; 1851, op. cit., p. 93; 1857, op. cit., p. 414.
Cœloria subdentata, Edwards & Haime, 1849: op. cit., p. 296; 1857, op. cit., p. 413.
Cœloria arabica, Klunzinger, 1879: Korallenth. roth. Meer., pt. iii, p. 17, pl. ii, figs. 1, 2, 3, 8; pl. ix, figs. 10*a–e*.

The best specimen in the collection is a large, massive block (J 1578), which I refer to var. *triangularis*, Klunz., but it is so eroded that the calices are destroyed, and the depth of the calicular furrows gives it some resemblance to var. *leptochila*, Ehr.

Klunzinger renamed the common Red Sea Cœloria *C. arabica*, though there are several names with prior right, and I have, therefore, adopted the oldest of them.

The specimens referable to *C. lamellina* are:—

J 1578, a large specimen of var. *triangularis*, Klunz.: raised beach, Camp 4, 80 feet above the sea, Wadi Hamrawein, near Qosseir.

J 2115, a specimen of var. *triangularis*, Klunz.: lower raised beach, north of Qosseir.

J 2234, a specimen of var. *subdentata*, Ed. & H.: raised beach, east of Gharib.

J 2231, a specimen of var. *leptochila* (Ehr.): raised beach, east of Gharib.

K 1630, a specimen of the typical form: raised beach, 80 feet above sea-level, Wadi Gueh, Qosseir.

FAVIA, Oken, 1815.

1. Favia lobata (Edwards & Haime), 1850.

Parastræa lobata, Edwards & Haime, 1850: Ann. Sci. nat., ser. III, vol. xii, p. 171.
Favia lobata, Edwards & Haime, 1857: Hist. nat. Cor., vol. ii, p. 434, pl. D 8, fig. 3.
Favia lobata, Klunzinger, 1879: Korallenth. roth. Meer., pt. iii, p. 31, pl. iii, fig. 9; pl. x, fig. 8.

Distribution. — Recent: Red Sea. Fossil, Pleistocene: raised beach, Camp 4, Wadi Hamrawein, near Qosseir, K 1633; lower raised beach, north of Qosseir, J 2143.

2. Favia ehrenbergi, Klunzinger, 1879, var. sulcata, Klunz.

Korallenth. roth. Meer., pt. iii, p. 29, pl. iii, figs. 5, 8.

Distribution. — Recent: Red Sea. Fossil, Pleistocene: raised beach, Camp 6, northern Wadi Queh, K 1577.

Some corallites of the *Favia ehrenbergi* type in a corallum of *Goniastræa pectinata*, J 1819 (see Pl. VII, Fig. 14).

GONIASTRÆA, Edwards & Haime, 1848.

1. Goniastræa retiformis (Lamarck, 1816).

Astræa retiformis, Lamarck, 1816: Anim. sans Vert., vol. ii, p. 265.
Goniastræa retiformis, Edwards & Haime, 1850: Ann. Sci. nat., ser. III, vol. xii, p. 161.

Goniastræa retiformis, Klunzinger, 1879: Korallenth. roth. Meer., pt. iii, p. 36, pl. iv, fig. 5.

Distribution. — Recent: Red Sea, Indian and Pacific Oceans. Fossil, Egypt: raised beach, 50 feet above sea-level, Jemsa, J 2032; lower raised beach, north of Qosseir, J 2118; raised beach, east of Gharib, J 2232.

2. Goniastræa pectinata (Ehrenberg), 1834.

Astræa pectinata, Ehrenberg, 1834, Beitr. Corallenth: Abh. k. Akad. Wiss. Berlin für 1832, p. 320.
Goniastræa pectinata, Klunzinger, 1879: Korallenth. roth. Meer., pt. iii, p. 34, pl. iv, fig. 6.

Distribution. — Recent: Red Sea. Fossil, Pleistocene: lower raised beach on coast plain, north of Qosseir, J 2119; raised 50 feet beach, Jemsa, south of Jebel Zeit, J 1819.

The specimen (J 1819) is of interest, as it shows one of these cases in which some of the corallites of the same specimen would, if found dissociated, be assigned to distinct genera. Part of the surface is shown on Pl. VII, Fig. 14. The narrow walled corallites on the left side of the figure agree with *G. pectinata*; but those in which the calices are separated by wide valleys, so that even the costæ of the adjacent corallites do not unite, have the form of *Favia ehrenbergi*.

Such occurrences show that the plasticity of the corals is such that occasional abnormal polypes may suddenly acquire the characters of another genus.

3. Goniastræa favus (Forskal), 1775.

Madrepora favus, Forskal, 1775: Descr. Anim. Itin. Orient, p. 132.
Goniastræa favus, Klunzinger, 1879: Korallenth. roth. Meer., pt. iii, p. 35, pl. iv, fig. 4; pl. x, fig. 7.

Distribution.—Recent: Red Sea, Indian Ocean. Fossil, Pleistocene: raised beach, 50 feet above sea-level, Jemsa, J 2032.

SOLENASTRÆA, Edwards & Haime, 1848.

1. Solenastræa chalcidicum (Forskal), 1775. (Pl. VII, Fig. 12.)

Madrepora chalcidicum, Forskal, 1775: Descr. Anim. Itin. Orient., p. 136.
Cyphastræa chalcidicum, Klunzinger, 1879: Korallenth. roth. Meer., pt. iii, p. 53, pl. v, fig. 8; pl. x, fig. 11.

Distribution. — Recent: Red Sea. Fossil, Pleistocene: raised beaches near Qosseir.

Figures.—Pl. VII, Fig. 12, part of the surface of a worn corallum of J 2140, from near Qosseir, by 2 diam.

J 1633, a very altered specimen, but judging by the cellular exotheca and rudimentary columella it is *S. chalcidicum* rather than *S. serailia*, the alternative identification: Camp 4, Wadi Hamrawein, north-west of Qosseir, Eastern Egypt.

H 1633*b*: Camp 4, Wadi Hamrawein.

H 1633*c*, a very weathered specimen, bored by Lithodomi: Camp 4, Wadi Hamrawein.

H 1633*f*: Camp 4, Wadi Hamrawein.

J 2122, 2138, two young coralla, one 27 mm. diam.: lower raised beach, north of Qosseir.

J 2136, a well-preserved specimen: lower raised beach, north of Qosseir.

J 2140, two specimens with dense walls: lower raised beach, north of Qosseir.

J 2149: lower raised beach, north of Qosseir.

1623, a much altered specimen, which, however, retains some of the original surface, showing the extent of projection of the calicinal edges: raised beach, Camp 4, Wadi Hamrawein, near Qosseir.

1628, a well-preserved specimen: 80 feet above sea-level, Wadi Queh, near Qosseir.

2. Solenastræa serailia (Forskal), 1775.

Madrepora serailia, Forskal, 1775: Descr. Anim. Itin. Orient., p. 135.
Cyphastræa serailia, Klunzinger, 1879: Korallenth. roth. Meer., pt. iii, p. 52, pl. v, fig. 4; pl. x, fig. 12.
Solenastræa forskalana, Edwards & Haime, 1850: Ann. Sci. nat., ser. III, vol. xii, p. 123; 1857, Hist. nat. Cor., vol. ii, p. 497.

Distribution. — Recent: Red Sea. Fossil, Pleistocene: raised beach, east of Jebel Esh, J 2177.

This specimen has the more compact exotheca and the equality of the septa of the first and second cycles, which are two of the chief distinctions of this species as compared with *S. chalcidicum* (Forsk.).

3. ? Solenastræa savignyi (Ed. & H.), 1850.

Cyphastræa savignyi, Edwards & Haime, 1850: Ann. Sci. nat., ser. III, vol. xii, p. 115.
Cyphastræa savignyi, Klunzinger, 1879: Korallenth. roth. Meer., pt. iii, p. 51, pl. v, fig. 7.

This specimen (J 1826) is a large block with long, thin corallites, about $2\frac{1}{2}$–3 mm. in diameter. It agrees with this species by its compact endotheca, and the marked inequality of the primary and secondary septa. But the specimen has been so altered that its identification is not free from doubt.

ORBICELLA, Dana, 1848.

1. Orbicella forskali (Edwards & Haime), 1849.

Astræa forskaliana, Edwards & Haime, 1849, Mon. Astr.: Ann. Sci. nat., Zool., ser. III, vol. xii, p. 100.

For Egyptian references and synonyms, see Gregory, 1898, Egypt. Foss. Madrep., Geol. Mag., Dec. IV, Vol. V, p. 242.

Distribution.—Recent: Red Sea. Fossil, Pleistocene: low-level and high-level raised reefs, near Jebel Zeit; also near Qosseir, Wadi Abu Shigeli, and Wadi Barud.

H 1633*c*; this specimen is much weathered, and has no trace of the surface, but the available characters are the same as those of J 2138: Camp 4, Wadi Hamrawein, near Qosseir.

J 1669, a specimen with the calices 6–8 mm. in diam.; the corallites are circular and not elliptical as in *O. mammillosa*: raised beach, 80 feet above sea-level, Wadi Abu Shigeli.

J 1789, a block with corallites 7 mm. in diam.: old beach, Camp 7, Wadi Barud.

J 2138, a small specimen but with well-preserved characters: lower raised beach, north of Qosseir.

2. Orbicella mammillosa, Klunzinger, 1879.

Korallenth. roth. Meer., pt. iii, p. 49, pl. v, fig. 5; pl. x, fig. 10.

Distribution.—Recent: Red Sea. Fossil, Pleistocene: Egypt and Gulf of Tadjura (Faurot), lower raised beach, north of Qosseir, No. J 2145.

This specimen is worn and is fragmentary; it has three cycles of septa, a large columella, and some of the corallites are oval in section. In a previous paper (Geol. Mag., 1898, p. 242) I included this *Orbicella* in *O. forskali*, and I still think that it may well be merged in that species. But as it is necessary to contrast these fossils as closely as possible with the recent Red Sea fauna, I am, for this purpose, recording the specimen under Klunzinger's name. The following species is provisionally accepted for the same reason.

3. Orbicella laxa, Klunzinger, 1879.

Op. cit., pt. iii, p. 49, pl. v, fig. 3; pl. x, fig. 9.

Distribution.—Recent: Red Sea. Fossil, Pleistocene: Egypt.

H 1633, a large block with thin walls, thickened by some secondary calcification: Camp 4, Wadi Hamrawein, near Qosseir.

H 1633*d*, a specimen with corallites varying from 8 to 10 mm. in diam.: Camp 4, Wadi Hamrawein, near Qosseir.

K 1663, a specimen with somewhat smaller calices, 7 mm. in diam. The corallites are close, and have very little exotheca; the walls are thin, and the septa number 27 to 30. None of the surface is shown. This is the coral which differs most from the central type of *O. laxa*, but I do not see any adequate reason for excluding it from that species: 380 feet above sea-level, near Camp 7, Wadi Shigeli.

ECHINOPORA, Lamarck, 1816.

1. Echinopora fruticulosa (Ehrenberg), 1834.

Stephanocora hemprichii, forma *fruticulosa*, Ehrenberg, 1834, Beitr. Korallenth.: Abh. k. Akad. Wiss. Berlin für 1832, p. 301.

Echinopora fruticulosa, Klunzinger, 1879: Korallenth. roth. Meer, pt. iii, p. 55, pl. vi, fig. 4.

Distribution.—Recent: Red Sea. Fossil, Pleistocene: Egypt, 380 feet above sea-level, near Camp 7, Wadi Shigeli, K 1660.

This specimen is the irregular nodular base of a coral with calices 5–5·5 mm. in diameter, so they are somewhat smaller than in the recent corals, and the paliform processes are perhaps less distinct. It is, moreover, not raised in definite branches, but would probably have developed thus had it grown larger. In other respects it appears to be the same as the recent forms.

K 1665, from the same locality, is a fragment of *Echinopora*, but is specifically indeterminable.

GALAXEA, Oken, 1815.

Galaxea fascicularis (Linnæus), 1767.

Madrepora fascicularis, Linnæus, 1767: Syst. Nat., 12th ed., vol. i, pt. 2, p. 1278.
Madrepora fascicularis, Ellis & Solander, 1786: Nat. Hist. Zooph., p. 151, pl. xxx.
Galaxea fascicularis, Oken, 1815: Lehrb. Naturgesch., Th. iii, Zool., Abt. 1, p. 73.
Galaxea fascicularis, Klunzinger, 1879: Korallenth. roth. Meer., pt. ii, p. 78.

Distribution. — Recent: Red Sea. Fossil, Pleistocene: raised beach, 80 feet above sea-level, Wadi Queh, near Qosseir, K 1629; Camp 6, Wadi Queh, K 1631.

These are two excellent specimens. The septa of the primary and secondary cycles are subequal, and the corallites are from 6·5 by 9 mm. or 6·5 by 10 mm. in diameter, and they are not gyrose or so compressed as in *G. irregularis*, Ed. & H.

LEPTASTRÆA, Edwards & Haime, 1848.

Leptastræa ehrenbergana, Edwards & Haime, 1850.

Ann. Sci. nat., ser. iii, vol. xii, p. 120; and Hist. nat. Cor., vol. ii (1857), p. 494, pl. d 7, fig. 4.

Distribution.—Recent: Red Sea. Fossil, Pleistocene: the raised beach between Jebel Mellaha and Jebel Zeit, J 2160; raised beach, 80 feet above sea-level, Wadi Queh, K 1586.

This species has polygonal calices, a well-developed papillary columella, and 24 to 30 septa. In No. J 2160 the calices are 4–7 mm. in diameter.

PRIONASTRÆA.

1. Prionastræa pentagona (Esper), 1795.

Madrepora pentagona, Esper, 1795: 'Pflanzenth.' Forsetz., p. 23, pl. xxxix.
Prionastræa pentagona, Klunzinger, 1879: Korallenth. roth. Meer., pt. iii, p. 41, pl. iv, fig. 11; pl. x, figs. 6, *a*, *b*.

Distribution.—Recent: Red Sea, Egypt. Fossil, Pleistocene: lower raised beach, north of Qosseir, J 2142 and J 2150.

2. Prionastræa tesserifera, Ehrenberg, 1834.

Astræa tesserifera, Ehrenberg, 1834, Beitr. Corallenth.: Abh. k. Akad. Wiss. Berlin für 1832, p. 321.
Prionastræa tesserifera, Edwards & Haime, 1851: Pol. Terr. palæoz., p. 102.
Prionastræa tesserifera, Klunzinger, 1897: Korallenth. roth. Meer., pt. iii, p. 37, pl. iv, fig. 9.

Distribution.—Recent: Red Sea. Pleistocene: Sinai, north end of the Quarantine Enclosure, El Tor, L 4193. Egypt, raised beach east of Jebel Esh, J 2177 (two specimens).

3. Prionastræa vasta, Klunzinger, 1879.

Korallenth. roth. Meer., pt. iii, p. 38, pl. iv, figs. 8, 12; pl. x, figs. 4, *a*, *b*.

Distribution.—Recent: Red Sea. Fossil, Pleistocene: Egypt, raised beach, east of Gharib, J 2226.

Klunzinger has founded this species, which he admits as a very near ally of *Prionastræa tesserifera*, owing to the greater size of its calices; in *P. tesserifera* he records them as from 10 to 12 mm. wide and from 10 to 15 mm. long, while those of *P. vasta* he

records as 10–15 mm. wide and 10–20 mm. long; but in his own photograph of *P. tesserifera* one of the calices is 20 mm. long, and they vary so much in different parts of the colony that *P. vasta* seems to me only a variety of *P. tesserifera* with large corallites. But for the sake of precise comparison between the recent and fossil faunas the species may be provisionally accepted.

SIDERASTRÆA, Blainville, 1830.

1. Siderastræa savignyi, Edwards & Haime, 1850.

Siderastræa savignyana, Edwards & Haime, 1850: Ann. Sci. nat., ser. III, vol. xii, p. 140.
Siderastræa savignyana, Klunzinger, 1879: Korallenth. roth. Meer., pt. iii, p. 77.
Astræa savignyana, Edwards & Haime, 1857: Hist. nat. Cor., vol. ii, p. 508.

Distribution. — Recent: Red Sea. Fossil, Pleistocene: Egypt (*fide* Edwards & Haime); also at raised beach, east of Jebel Esh, J 2172–2190.

2. Siderastræa lilacea, Klunzinger, 1879.

Korallenth. roth. Meer., pt. iii, p. 77, pl. ix, fig. 6; pl. x, figs. 16, *a*, *b*.

Distribution.—Recent: Egypt, near Qosseir (Klunzinger). Fossil, Pleistocene: lower raised beach, north of Qosseir, J 2122–2138; raised beach, east of Jebel Esh, J 2186.

The specimens, Nos. J 2122–2138, include three nodular coralla, of which the two more perfect ones are 56 by 42 mm. in diameter and 25 mm. high, and 29 by 27 mm. in diameter and 13·5 mm. high.

FUNGIA, Lamarck, 1801.

I have previously called attention to the variability of the Fungiæ found in the Pleistocene deposits of Egypt.[1] Klunzinger accepts four previously described species as found in the Red Sea, and founded three more. He divided them primarily according to the septal teeth, and his secondary division is based on the circular or elliptical form of the corallum. The specimens included in the present collection do not seem to me to agree with Klunzinger's scheme, as they represent a union of characters. But accepting Klunzinger's arrangement for the sake of convenience, the Fungias in this collection can be named as follows: —

1. Fungia patella (Ellis & Solander), 1786.

Madrepora patella, Ellis & Solander, 1786: Nat. Hist. Zooph., pl. xxviii, figs. 1–4.
Fungia patellaris, Lamarck, 1801: Syst. Anim. sans Vert., p. 370.
Fungia patella, Klunzinger, 1879: Korallenth. roth. Meer., pt. iii, p. 61, pl. vii, fig. 4; pl. viii, fig. 2.

Distribution. — Recent. Fossil, Pleistocene: Egypt, R 1308, Brit. Mus. (Gregory, op. cit.), Sinai, Lower Terrace, south of Hedemia Bay, L 3498.

2. Fungia valida, Verrill. (Pl. VII, Fig. 13.)

Bull. Mus. Comp. Zool., No. 1, p. 51.

Distribution.—Recent: Indian Ocean (Zanzibar). Fossil, Pleistocene: Egypt, Wadi Queh; Sinai, Lower Terrace, south of Hedemia Bay.

[1] Geol. Mag., Dec. IV, Vol. V (1898), p. 244.

Figures.—Pl. VII, Fig. 13, part of a young corallum from the side, nat. size.

K 1560, a set of five specimens ranging from 20 by 21·5 mm. in diameter and 5·5 mm. thick to 60 by 58 mm. in diameter and 11 mm. thick. One specimen figured on Pl. VII, Fig. 13, retains the anthoagathus: raised beach, Camp 6, Northern Wadi Queh.

K 1589, one well-preserved specimen from the Wadi Queh.

L 3498, two specimens, the larger of which is 73 by 67·5 mm. in diameter, and about 11 mm. thick: Sinai, Lower Terrace, south of Hedemia Bay.

L 3498, three smaller specimens, of which the largest is 57 by 52·5 mm. in diameter and 11 mm. high, and its costæ resembles *F. placunaria*, Klunz.: same locality.

PORITES, Edwards & Haime, 1860.

1. Porites solida (Forskal), 1775.

Madrepora solida, Forskal, 1775: Descr. Anim. Itin. Orient., p. 131.
Porites solida, Klunzinger, 1879: Korallenth. roth. Meer., pt. ii, p. 42, pl. vi, fig. 14; pl. v, fig. 21.

Distribution. — Recent: Red Sea. Fossil, Pleistocene: Egypt, lower raised beach, north of Qosseir, Nos. J 2116 and J 2134.

These specimens closely resemble *P. lutea*, Edwards & Haime,[1] but their pali are less distinct, and so I record them under Klunzinger's name. The depth of the calices cannot be determined in these specimens.

2. Porites nodifera, Klunzinger, 1879.

Korallenth. roth. Meer., pt. ii, p. 41, pl. vi, fig. 13; pl. v, fig. 17.

Distribution. — Recent: Red Sea. Fossil, Pleistocene: Egypt, raised beach, 80 feet above sea-level, Camp 8, Wadi Abu Shigeli, Coast Plain, north of Qosseir.

This specimen is 70 mm. high, and above the base the transverse section is elliptical, being 47 mm. wide by 28 mm. thick. The corallum divides above into short, thick branches. The walls are very thin and trabecular; the pali are fairly distinct, but the columella is not very apparent; but these structures are not well defined in the irregularly trabecular skeleton of this genus.

MONTIPORA, Quoy & Gaimard, 1833.

Montipora sp.

No. J 1826, old beach, Camp 17, Wadi Barud. The collection made by Mr. Barron from this locality includes a worn fragment of a *Montipora*. But it is too imperfect for determination as to its position in a genus, which, according to Mr. Bernard's Catalogue, includes 140 recent species.

The collection includes some indeterminable specimens as follows:

K 1656, cast probably not a coral: raised beach, 300 feet high, Wadi Hamrawein.

[1] Edwards & Haime: Hist. nat. Cor., vol. iii, p. 180.

K 1632, cast of a *Lithodomus*: raised beach, No. 1, north of Qosseir.
H 1633*a*, ? *Favia*: Camp 4, Hamrawein, near Qosseir.
K 1640, (*a*) Prionastræoid, indet., (*b*) *Acanthastræa* sp., (*c*) indet.: raised beach, No. 1, 520 feet high, north of Qosseir.
K 1664, an Orbicelloid: raised beach, 380 feet above sea-level, Wadi Shigeli.
H 1776, ? *Mussa* sp.: Abu Sha'ar Plateau.
H 1866*a*, ? *Orbicella*: Wadi Belih.
J 1826, *Acanthastræa* sp.: old beach, Camp 17, Wadi Barud.

DESCRIPTION OF PLATES.

PLATE VI.

FIG. 1.—*Smilotrochus* sp. Abu Roash. No. 3795. *a*, seen from the side; *b*, outline as seen from above. Nat. size.
,, 2.—*Favia humei*, n.sp. Miocene: Wadi Belih, Abu Sha'ar. No. H 1780. Part of surface of the corallum. × 1½ diam.
,, 3.—*Orbicella mellahica*, n.sp. Miocene: west flank of Jebel Mellaha. Part of the surface of H 1862. × 1½ diam.
,, 4.—The same. Some corallites of 1818*b*. × 2 diam.
,, 5.—*Orbicella schweinfurthi* (Felix). Miocene: west flank of Jebel Mellaha. Part of the surface of H 1862 (duplicate). Nat. size.
,, 6.—*O. defrancei* (Edwards & Haime). Miocene: west flank of Jebel Mallaha. H 1862. A few corallites from a transverse section. × 1½ diam.
,, 7.—*Stylina tetramera*, n.sp. Miocene: Abu Sha'ar. H 1818. Part of the surface of corallum. × 2 diam.
,, 8.—*Leptastræa barroni*, n.sp. Miocene: surface of Abu Sha'ar Plateau. H 1864. *a*, part of surface; *b*, another part of surface of same specimen; *c*, part of internal section. × 2 diam.

PLATE VII.

FIG. 9.—*Stylocœnia tuberculata*, n.sp. Miocene: Wadi Belik. H 1814. *a*, the coral, seen from side; nat. size. *b*, part of the surface; × 2 diam.
,, 10.—*Prionastræa lyonsi*, n.sp. Miocene: Wadi Belih. H 1814*a*. *a*, part of worn surface; *b*, part of transverse section. Nat. size.
,, 11.—*Solenastræa elliptica*, n.sp. Miocene: Abu Sha'ar. H 1818*a*. *a*, part of the surface; × 2 diam. *b*, part of a transverse section; × 4 diam.
,, 12.—*Solenastræa chalcidicum* (Forsk.). Pleistocene: raised beach near Qosseir. J 2140. Part of the surface of a worn corallum. × 2 diam.
,, 13.—*Fungia valida*, Verrill. Pleistocene: Wadi Queh. K 1560. Corallum from side. Nat. size.
,, 14.—*Goniastræa pectinata* (Ehr.). Pleistocene: Jemsa, south of Jebel Zeit. J 1819. Part of the surface of the corallum. Nat. size.

IV.—ALLOTROPIC FORMS OF SILICA AND THEIR SIGNIFICANCE AS CONSTITUENTS OF IGNEOUS ROCKS.

By COSMO JOHNS, M.I.Mech.E., F.G.S.

THAT silica appears as a constituent mineral of igneous rocks in two distinct phases, viz. quartz and tridymite, has been known for some time. The writer is not aware that any explanation has been offered which would indicate the conditions determining the appearance of one or the other in a cooling fused rock-mass. He now proposes to describe certain experiments made with a view to explain why it is that though the free silica generally appears as quartz, yet occasionally, as in certain trachytes, it crystallizes out as tridymite.

He was also desirous of clearing up, if possible, the difficulty caused by the conflicting values given to the fusion-point of silica by different investigators. Joly,[1] using the meldometer, found quartz to fuse at 1200° C., and, with prolonged heating, even at much lower temperatures. Boudouard,[2] in the course of his observations on calcic and alumino-calcic silicates, used Seger cones and determined the fusion-point of silica to be 1830° C. Other experimenters have given values varying from 1450° to 1550° C. It is very evident that the differences are too great to be explained by suggesting experimental errors as the cause.

Advantage was taken of the fact that a regenerative gas furnace, whose temperature could be regulated and only limited theoretically by the dissociation point of carbon dioxide, was available to make a series of experiments with quartz sand of a high degree of purity.

After its specific gravity had been determined, a quantity was introduced into the furnace, rapidly heated to 1500° C., and maintained at that temperature for 48 hours. When withdrawn the material was quite pulverent, and did not show the slightest signs of fusion. It had, however, increased in volume and become milk-white in appearance. Selecting the hottest part of the furnace, where the temperature was determined to be above 1800° C., another portion of similar sand was introduced and withdrawn after 30 minutes exposure to that high temperature. On examination the surface of the mass was found to be fused to a depth of 7 or 8 mm., but the remainder was in the same pulverent state as that found after the first experiment.

Both experiments were repeated, but it was found that quartz sand could only be fused with great difficulty, and only by selecting the hottest part of the furnace. Yet at the same time the temperature of the furnace was such that steel was being maintained in a fluid state with ease. It would seem that Boudouard's determination is confirmed, and the fusion-point of silica lies above 1800° C.

Reference has been made to the fact that the unfused sand had increased in volume during both experiments. This was confirmed when the specific gravity was determined, for the results were as follows :—

Original quartz sand	2·645 sp. gr.
After prolonged exposure to 1500° C.	2·309 ,,

The specific gravity of the original quartz sand is that of a very pure quartz, and this only confirms the analysis, which showed it to be practically pure silica. The specific gravity of the altered and unfused mass is the average of tridymite. The quartz had, in fact, been transformed into another phase, and later experiments indicated the transformation point to be about 1300° C. It is hoped to make further experiments and determine the point more accurately.

It becomes apparent that silica may exist in two solid phases, viz. quartz and tridymite. Also that the former is only stable

[1] Rep. Brit. Assoc., 1900, p. 730.
[2] Journ. I. and S. Inst., vol. i (1905), p. 350.

below 1300°, and, from Joly's experiments, fuses at 1200° or even lower. But tridymite is stable below 1800°, and only fuses when that temperature is exceeded. Those familiar with the phase rule will remember instances of a substance having two solid phases each with a different fusion-point. It should also be noted that it was by rapidly heating the quartz up to and beyond the transformation point that the higher fusion-point was realized.

The vapour pressure would have some effect in modifying the temperature of fusion of these two phases of silica, and though, owing to the absence of data, this could not be profitably discussed here, yet it is a factor that should be considered when dealing with a cooling fused rock-mass.

The significance of the possibility of silica appearing in either of its two solid phases cannot be overlooked owing to its obvious bearing on the question of the thermal conditions attending the consolidation of the igneous rocks. Treating the cooling mass as a case of reciprocal solution, it would appear that the temperature at which silica may be thrown out of solution is a critical point of some importance. If it happens to be above 1300° C., and neglecting for the present the effect of vapour pressure, then the silica would appear in the form of tridymite. If the temperature of the mass happened to be below 1300° C. when silica was thrown out of solution, then quartz would appear.

Quartz is generally one of the later minerals to appear in a cooling rock-mass, therefore its predominance in igneous rocks as a phase of silica is not surprising. The comparative rarity of the tridymite phase would also be explained. If the correctness of the writer's conclusions be admitted, then we are able to fix within moderate limits the temperature of certain critical points in the cooling curves of the igneous rocks.

There is, of course, just a possibility that tridymite is really metastable below the transformation point, but that it requires a long period of time before passing into the more stable form. In that case the geological age of the tridymite-bearing rocks becomes a factor of some importance.

V.—The Thickness of the Ice-Cap in the various Glacial Periods.

By Ernst H. L. Schwarz, A.R.C.S., F.G.S.,
Rhodes University College, Grahamstown, South Africa.

In estimating the maximum load which pressed upon the northern type of Glacial (Dwyka) Conglomerate in Prieska, Cape Colony, I assumed that the calculations of Sir Wyville Thomson and Bernacci were correct, and that the greatest column of ice that could exist on the earth's surface was from 1,400 to 1,600 feet high.[1] This limit, however, is by no means accepted by European glacialists, who, though they do not go as far as Dr. Croll in assuming

[1] "An Unrecognized Agent in the Deformation of Rocks": Trans. S. African Phil. Soc., vol. xiv (1903), p. 400.

thicknesses of 120,000 feet, yet see no reason why there could not have been ice-sheets 5,000 feet thick. The publication of Captain Scott's narrative of the voyage of the "Discovery" has given us certain definite data from the Antarctic which enable the case for the 1,600 feet maximum to be put with more confidence, and I will endeavour in the present paper to state the main lines of the argument. The question is of importance not only to us in South Africa with our two Palæozoic ice-ages, but to all geologists, as it affects the problem of the earth's equilibrium. To give a recent example, Professor Penck, in describing the Bodensee, discusses whether the weight of ice pouring down from the Alps in a sheet 3,600 feet thick may not have had some effect in producing a sinking in the earth's crust.[1]

To begin with, it is necessary to enquire into the thickness of the ice-sheet at the present day, and in no case where there has been direct measurement has the ice been found to exist in sheets surpassing the 1,600 feet limit. The estimates of the thickness of the Greenland ice-cap rest on assumptions which it is impossible to prove or disprove, but if they are examined closely they will be found to be as favourable to the lesser limit as to the greater one of 6,000 feet. Dr. Nansen's argument is that the coastline of Greenland is very like that of Scandinavia, and therefore it is permissible to assume that the internal relief of the island continent is the same as that of Norway and Sweden; if the latter were covered with an ice-sheet up to the tops of the mountains the valleys would be filled with ice to depths of 6,000 to 7,000 feet; consequently, in Greenland, allowing for the land surface being somewhat higher than in Scandinavia, the valleys would have accumulations of ice 5,000 to 6,000 feet thick. As confirmatory evidence Dr. Nansen quotes instances of the enormous erosion which has gone on along the coast of Greenland, which he states was produced by glaciers excavating their valleys while filled with ice and giving at the foot pressures of not less than 160 atmospheres.[2]

Von Drygalski, as the result of two expeditions to Greenland, has given elaborate measurements of the glaciers that now end in the sea, and concludes that an iceberg rises higher than the glacier front from which it has calved only when it turns over on its side;[3] as the glacier front, where it is floating, rarely rises to 300 feet, icebergs of more than 300 feet high must be ones that have turned over, and are consequently of no use in measuring the height of the original ice-sheet from which they have issued. If we take Steenstrup's figures for the proportion of the parts of an iceberg above and below water, namely, 1 : 7·4 to 1 : 8·2,[4] a height of 300 feet would make an iceberg have a base over 2,000 feet deep. Von Drygalski, however, found that soundings off the edge of

[1] Vorträge d. Vereins z. Verbr. Naturwiss. Kennt., xlii (Vienna, 1902), Heft 6, p. 11.

[2] "The First Crossing of Greenland," Appendix, p. 472; London, 1890.

[3] "Gronland Expedition," p. 387; Berlin, 1897.

[4] "Meddeleser om Gronland," p. 97; Copenhagen, 1879.

floating glaciers gave only a depth of four times the height of the glacier front, and a 300 feet iceberg would therefore be 1,500 feet thick in all. Scott says the same thing for the Antarctic, where 120 to 150 feet icebergs do not touch bottom in more than 100 to 120 fathoms of water, giving a proportion of something like 1 : 5 for the portions above and below water.[1] The discrepancy between the estimated and observed proportions is explained by the experiment performed by the "Challenger" in firing cannon-balls into an iceberg: while some layers reacted like solid rock, others were so soft that the balls imbedded themselves, proving that a large proportion of the berg was soft, spongy, and filled with air, thus making it buoyant.

Scott found that the Great Barrier ice rose at one point to 240 feet above sea-level, but as some portions sank to nearly sea-level, these greater elevations may safely be put down to pressure ridges; the average height was under 200 feet. The height of the ice-column in the Great Barrier may give too low a figure for the mass of ice as it leaves the land, whereas that of the Greenland glaciers, coming steeply off the land, probably gives too high a one. The point I wish to emphasize is that the whole resources of the Greenland ice-cap and the great snow-fields of the Antarctic, can only produce a sheet of ice in the valleys or places of greatest accumulation of heights that are near the estimated possible maximum, namely, 1,600 feet.

These estimations depend on the ice being 0° C. at the junction of the sheet with the earth, and doubt has been thrown on this. Ice only becomes colder than its melting-point by reason of radiation of heat into space, and where this is stopped by great thickness of ice —ice being a bad conductor of heat—the temperature of the ice will rise from any degree below zero at the surface to 0° C., where the heating effect due to pressure comes into play. V. Drygalski has given a large series of observations bearing on this question, and the same rise of temperature is observed as in the case of the earth's crust, only on a more exaggerated scale. The following are a few extracts, temperatures in degrees Centigrade (Celsius in the original) :— [2]

Temperature in the Ice on the Great Karajak Glacier, 175 m. above sea-level.

	6 in. (·15 m.)	17·5 ft. (5·4 m.)	28·9 ft. (8·9 m.)
30th October, 1892 ...	— 13·7	— 3·7	— 2·9
19th November, 1892 ...	— 13·7	— 10·1	— 7·2
29th November, 1892 ...	— 19·2	— 5·5	— 5·2
2nd February, 1893 ...	— 32·9	— 6·1	— 5·0
14th April, 1893 ...	— 15·0	— 9·0	— 9·2

The last figure in the third column is the greatest cold found at this depth; it was taken on April 14th, and denotes the lag in the temperature of the interior of the ice-sheet when the surface was becoming warmer. These figures demonstrate sufficiently clearly

[1] "Voyage of the 'Discovery,'" p. 410; London, 1905.
[2] "Greenland Expedition," pp. 451–2.

that the lowering of the melting-point of ice due to pressure is not materially affected by the intense cold at the surface, and that therefore we may take the physicists' estimate of the maximum thickness as approximately correct.

Scott found the Antarctic ice-cap to be flat on the surface of the land with an edge of rock which, from the sea, appeared to consist of lofty mountains, but the highest points of these sank below the horizon directly the level of the ice-cap was reached. Peary and Nansen have found the same thing in Greenland. The tops of the mountains look as if they once were part of a peneplain, but Nansen maintains that it is not likely that a great land-mass like Greenland should be all on a level beneath the ice. In his later researches, however, Nansen has demonstrated the existence of a vast submarine plateau in the Arctic Ocean, and if the plateau here rose above the sea by block-uplift it would be covered by ice and protected from denudation by ice. Douglas Freshfield, in his address to the British Association at Cambridge, stated that it is at the face of the glacier that denudation begins, and the configuration of the coastline in Greenland and in the Antarctic regions bears this out; the valleys go but a short way inland, and are ended abruptly. If, then, there is some reason to suppose that the polar ice-caps lie on level land, the argument for estimating the thickness of ice above the limit which physicists say is the maximum is shown to be of doubtful value.

The only way by which a sheet of ice over the 1,600 feet limit can exist is when the surface of the ground on which it rests is below the temperature of the melting-point of ice, and to obtain such a condition of things there must be a cause of abstraction of heat from within the earth, as the ice-sheet forms a blanket to protect the surface of the ground from radiation from above. The heat of the earth's interior is always creeping outwards, and instead of abstracting heat from the ice it is the ice that is abstracting heat from the earth. Not only is this true for the existing ice-caps, but it must have been true for the ice in the Glacial periods of the northern hemisphere and the Palæozoic ice-ages of the southern, and I cannot, therefore, see how it is possible, in the light of physical experiment, supplemented by actual observation, to obtain the great thickness of ice that glacialists ordinarily call in to explain the phenomena which they have described.

Finally, there is one observation of Commander Scott's[1] which perhaps explains the enormous apparent thickness of glacier ice in past ages as seen in the evidence afforded by ice-scorings on the sides of the valleys. In the Ferrar glacier the ice had once been from 3,000 to 4,000 feet higher than it is at present. There is also reason to suppose that the climate was milder at the period of maximum glaciation, because it is physically impossible for cold air to contain much moisture and consequently to feed the glacier streams. With a milder climate the ice must have melted more easily, and yet even

[1] "Voyage of the 'Discovery,'" p. 416.

now within the Arctic circle glaciers have streams of running water issuing from their fronts; there must have been, therefore, very great erosion in the glacier valleys by running water during the maximum glaciation, and the valleys became rapidly deepened. When the climate became severer and the glaciers became smaller owing to insufficiency of supply, they no longer flowed down the valley as it originally existed, but in the narrower gorges excavated by the sub-glacial streams in earlier times. This fact, that during maximum glaciation there was necessarily a milder climate and consequent greater melting and erosion, may perhaps explain how glacier valleys in Europe and America have been scored by ice from their bottoms to heights of 3,000 and 4,000 feet above. To maintain that such valleys at one time were filled from top to bottom with ice is, to my mind, equivalent to saying that in an ordinary river valley, with terraces high up the sides, the valley was once filled with water from the present level to the topmost water-mark.

VI.—Further Notes on the Stratigraphy and Fauna of the Trimmingham Chalk.

By R. M. Brydone, F.G.S.

(PLATES VIII AND IX.)

(*Concluded from the February Number, p. 78.*)

THE very uniform trend of all these ridges will have been noted, but my previous remarks on the general strike of the foreshore chalk require considerable modification. The whole of the chalk so far exposed may be divided into four sections. Each of these comprises an exposure in or close to the cliff of what appears to be the highest part of a ridge running down the beach in a direction from 10° to 30° south of east (and sinking as it goes) to about the half-tide level. Here three of them (the exception being the brickfield chalk) turn and run for some way roughly parallel to the shoreline, and then resume their original direction and run out to sea. The brickfield chalk only varies from this plan by running out to sea with practically no change of direction on the way. Except where a ridge is running up to the cliff, the substratum of the beach is invariably glacial clay down to about half-tide level. Here it is either banked against what appear to be vertical faces of chalk or else (*between* the foreshore exposures) disappears under the sand. It has never been seen to run out to sea, and every time a fresh bit of the foreshore below the half-tide level is cleared of sand it is chalk that is revealed. In the case of the section attached to the north bluff there is below the half-tide level a continuous mass of chalk with perfectly regular bedding exposed for at least 1,000 yards along the shore, and directly opposite the north bluff I have myself seen chalk continuous from the foot of the bluff for over 200 yards straight out to sea (except about 20 yards close up to the bluff, which, however, are covered by Mr. B. B. Woodward's letter in the October (1905) number of the Geological Magazine), the regular sequence of the beds being only broken by

one fault. The section attached to the ridge coated with a sheet of flint is a good second in size, showing chalk in regular sequence for a length of over 400 yards, and maximum (exposed) breadth of about 45 yards.

There seem to be only two possible theories as to the nature of these chalk masses, as Mr. Reid's theory is quite impossible of general application, and appears to be only applicable to the north bluff subject to very important modifications. One is the erratic theory. This theory involves the possibility of an erratic 1,000 yards by 200 yards in superficial area and unknown depth, and others smaller but still of monstrous size. It offers no explanation of the rude symmetry of tectonic structure exhibited by the chalk, nor any plausible origin for these erractics, which have no known counterpart in fossil contents, and cannot from the perfection in which they have retained their stratification and fossil contents have travelled far. It is also a coincidence almost past belief, until every other possible explanation has failed, that an ice-sheet should chance to leave at one spot all the known remnants (a very large number) of a very strongly marked epoch without the admixture of a single erratic mass belonging to any other epoch. If a final nail in the coffin of the erratic theory be required, it is to be found in the Mundesley well section recorded in the Geological Survey Memoir on the Upper Chalk of England as having shown a great thickness of chalk, obviously *in sitû*, containing *O. lunata* at intervals.

The other theory is that of the buried chalk cliff, set forth in my previous pamphlet (of which Mr. Jukes-Browne's buried sea stacks are really a variant very near the truth, but not quite borne out by my investigations). The numerous sections on the foreshore where the clay is piled up against apparently vertical faces of chalk, the uniformity with which the clay has hitherto been found to be bounded to seaward by chalk, the occasional disturbances in the chalk along its junction with the clay never penetrating more than a short distance into the body of the chalk, the newly exposed cavities in the southern part of the south bluff, and the great masses of flint shingle in the cliffs immediately above the bluffs, all tend strongly to confirm the supposition that the chalk once presented at this point a low cliff with projecting headlands to a sea lying where now we have the land, and that up against this cliff the boulder-clay was piled. It is not at all uncommon to find the chalk much disturbed along the junction with the clay, while a few yards further seawards there commences an extensive area of wholly undisturbed chalk, and this is no doubt due to the dislocation of the chalk in the face of the old cliff by clay forced into cracks and acting under continued pressure from behind like a gigantic wedge. The erratics behind the north bluff have almost demonstrably been torn from the parent mass by clay pressing up from below, which must have reached a position below them either in caves or along cracks.

There are, as will have been gathered, many apparent instances on the foreshore of clay passing under the chalk. Some of these are

undoubtedly genuine cases, to be explained as above. But it is quite possible that the majority are only apparent. If boulder-clay was banked up against a vertical wall of chalk, the plane of junction would often be a waterway of some importance. The water percolating along this plane would, of course, have little or no effect on the boulder-clay, but would tend to dissolve away the chalk, and the deeper below the surface the water got the greater would be the pressure on it and consequently its solvent power. There would thus be a constant tendency for the chalk face to recede, and recede less rapidly at the surface than deeper down, and so to develop an overhanging vertical face. The clay, being comparatively plastic, would of course follow the receding chalk wall, and in time lie under the chalk for a short distance. The shortness of this distance would not be apparent in the foreshore sections we have, which are almost always along the chalk walls and never across them, but I have several times been able to satisfy myself by digging that the distance for which the infraposition of the clay to the chalk extended seawards was a matter of inches only.

It may perhaps be permissible to speculate on the epoch at which this chalk cliff existed. Now we know, of course, that the early Crag sea was a warm and tranquil sea, and therefore it must have been protected from the North Sea of the period by a land barrier, the gradual breaching of which would allow the gradual admission of colder water and Boreal forms, which can be so clearly traced in the upper Crag beds. Such a barrier, if it lay anywhere in or near Norfolk, must have been of chalk, which is the basement bed, so to speak, of the county, and we should therefore hope to find with great luck the cliffs left by the cutting through of the barrier, and possibly also the floor of chalk formed in the gap. Now we have between Cromer and Weybourne an almost flat surface of chalk at sea-level, which presumably has not been formed by the recent sea, as the cutting back of the cliffs always reveals a platform of chalk at their very base, which, except between Sheringham and Weybourne, shows no sign of rising into the cliff, and therefore must be of pre-glacial age. Is it fantastic to suggest that the chalk between Cromer and Weybourne is part of the floor of the old breach, and that at Trimmingham we have the only remains yet disclosed of the east cliffs formed by that breach, and that the west cliffs are buried at some point between the chalk at sea-level round Cromer and the chalk at a considerable height above it round Holt and Melton, a slight tilt having brought the cliffs at Trimmingham nearly down to modern sea-level? The behaviour of the Pliocene beds themselves confirms this supposition as to the relative Pliocene positions of the Trimmingham and Cromer chalk, for the Pliocene beds near Cromer are all above the surface of the chalk there, while we know on the authority of Mr. Reid that corresponding Pliocene beds at Trimmingham close by the chalk occur well below high tide mark, and consequently many feet *below* the highest point to which the undisturbed chalk there reaches in the south bluff. This theory would involve the existence at one time of a (probably now buried)

chalk cliff running along the bed of the North Sea, and such a cliff would be a possible source, and the only one that can be suggested, for the erratics between Trimmingham and Weybourne. Some cliff the source must have been, for ice with all its powers can neither shovel up nor suck up large masses of chalk out of a horizontal surface. This hypothetical buried cliff would probably be running more or less north and south, and would therefore be nearer to the present coastline at Overstrand than further north, and the difference in distance travelled would account for the enormous difference between the condition of the Overstrand erratics, which have suffered somewhat, but not much, from pressure, and those west of Cromer, which have been crushed until they are barely coherent, and crumble most rapidly on exposure. The suggested Pliocene chalk cliffs would also afford a source for the enormous supply of carbonate of lime which must have been required for the building up of the vast masses of shells of which the lower Crag beds are composed.

[After this paper had taken more or less its present shape, Professor Bonney and Mr. Hill published in the GEOLOGICAL MAGAZINE for September, 1905, a paper dealing somewhat sketchily with the purely stratigraphical aspect of the Trimmingham Chalk on apparently very incomplete data. This paper has been effectively criticized by Mr. B. B. Woodward in the October number of the same Magazine, pp. 478 and 479, and by Sir Henry Howorth in the November number, and I have nothing to add to the criticisms made by these gentlemen, to whom I am much indebted for their intervention. We have, however, to thank Professor Bonney and Mr. Hill for a record of chalk at the base of the cliff under Trimmingham itself, where I have long expected it, but never had the good fortune to see it.]

PALÆONTOLOGY.

A. *Chalk of Trimmingham.*

The greater number of the additions and corrections to the list given in my previous pamphlet have been incorporated in the list to be found in the recent Survey Memoir above referred to, but for convenience a complete list of all corrections and additions is given here :—

SPONGIDA.

Add *Porosphæra globularis*, Phill. ; *Ventriculites decurrens*, T. Smith ; *V. impressus*, T. Smith ; *V. quincuncialis*, T. Smith ; *V. radiatus*, T. Smith.

Omit *P. Woodwardi*—the light recently thrown by Dr. Hinde on the species which has so long borne this name makes me doubtful if I can prove its occurrence.

ACTINOZOA.

Add *Diblasus Grevensis*, Lonsd.

Omit *Calamophyllia faxensis*—the specimen which distantly suggested this species to Professor Deecke has proved to be a fish-spine (*Cœlorhynchus cretaceus*) ; *Onchotrochus serpentinus*—this appears to have been based on specimens of a very slender *Porina*.

ECHINODERMATA.

Add *Epiaster gibbus*, Lam. ; *Micraster cor-anguinum*, Klein. One specimen of the former and two of the latter are in the collection of Mr. Savin. *Echinoconus Orbignyanus*, Ag. (the bun-shaped *Echinoconus* of my previous pamphlet according to Mr. Sherborn).

CIRRHIPEDIA.

Add *Pollicipes fallax*, Darw. (very abundant).
Substitute *Brachylepas cretaceus*, H. Woodw., for *Pollicipes cancellatus*, which has proved to be a synonym.

POLYZOA.

Add *Siphoniotyphlus tenuis*, Hag., a species of remarkable range for one so specialised.

LAMELLIBRANCHIATA.

Add *Avicula cærulescens*, Nilss.; *Ostrea canaliculata*, Sow.; *O. inæquicostata*, S. Woodw.—if the Trimmingham specimens are rightly identified, this species can hardly be identical with *O. semiplana*, as suggested in the recent Survey Memoir; *Plicatula sigillina*, S. P. Woodw.; *Spondylus spinosus*, Sow.
Correct *Diceras inæquirostratus* in Survey Memoir. This record appears to be founded on adherent valves of an *Exogyra* so identified at South Kensington.

GASTEROPODA.

Add *Dentalium* sp. There frequently occur casts of Gasteropods, mainly *Trochus* and *Cerithium*, but so small and delicate as to require an expert to identify them.

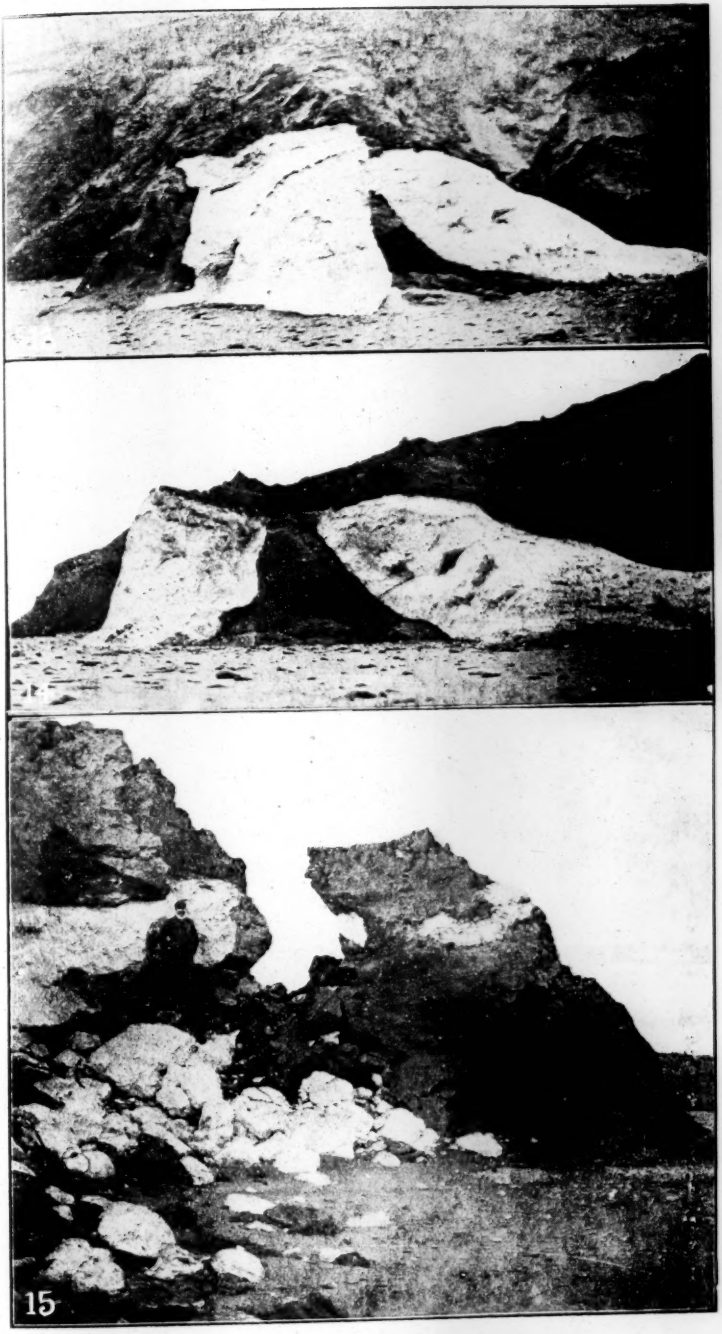
CEPHALOPODA.

Add *Bayfieldi*, F. & C., after *Nautilus*.
Substitute *Aptychus rugosus*, Sharpe, for *A. peramplus*.
Omit *Belemnitella* sp. Dr. Blackmore is convinced that the very numerous specimens of this slender form are only young *B. mucronata*, the infant mortality among which must have been terrible.

PISCES.

Add *Coelorhynchus cretaceus*, Dix; *Corax* sp.; *Scaphanorhynchus subulatus*, Ag.

It will, perhaps, be well to comment on some statements made by Dr. Rowe in his paper on the Dorset Chalk, in which he compares the fauna of the *B. mucronata* zone in Dorset and Norfolk, as they are calculated to mislead anyone having only a slight knowledge of the Trimmingham fauna. He states that *Pecten concentricus* is common at Trimmingham. As I have never seen a specimen of it there, I can only conclude that he is confusing the smooth *Pecten Nilssoni* (which is common at Trimmingham) with *P. concentricus*. He also states that a certain hexagonal *Serpula* was considered by me to be *S. difformis*, but that it differed from the Trimmingham examples, "which are always pentagonal." He has here confused at least three perfectly distinct species. The first is a free-growing, tapering, uniformly *heptagonal* form of carious surface, which is either *S. difformis* or a very near relation. This form, or one barely separable from it, occurs also in the *B. mucronata* chalk of Hampshire down to its base. The second is a very remarkable form with a *polished* surface. It starts with a broad base and triangular cross-section with a strong dorsal carina, and is then incapable of being separated from *S. macropus*. But very soon the tube rises free from the base and *proceeds* to develop six more carinæ placed at regular intervals round the tube. But the new carinæ are not all developed at once, and the specimen forwarded to me by Dr. Rowe for identification was, if I remember rightly, a youngish specimen with six carinæ fully developed and the seventh just appearing. This form is not uncommon in the *B. mucronata* chalk of Hampshire, but I have not yet found it (at any rate, to be certain of it) at Trimmingham. At the time I saw Dr. Rowe's specimen I was still under the impression that this form would prove to be



Views of the Trimmingham Chalk Bluffs, Norfolk Coast.

S. difformis, so I gave this name to Dr. Rowe, but with the same caution with which, it will be seen, I recorded it at Trimmingham in my previous pamphlet. Whether it ought to be included in the same species as the typical *S. macropus* on account of its initial stage is a question for a specialist, but it seems to me very undesirable, seeing how greatly the two forms differ in the adult stage. (The question is further complicated by a Trimmingham species, which generally begins with a *macropus* stage like the form just described, and then grows to a great length as a free round tube slightly curved, with a carious surface and devoid of carinæ. The same form is, however, often to be found in the same beds free from its earliest infancy.) *S. canteriata*, the third species, is evidently the Trimmingham form which Dr. Rowe had in mind, as it is the only free pentagonal species at Trimmingham (except occasional specimens of *S. fluctuata*). Not content with gratuitously attributing to me an intention to identify his specimen of a heptagonal form with *S. canteriata*, which is never even hexagonal, he has made misstatements about that species from which a wider experience would have saved him. If he had said it was always pentagonal outside the Trimmingham Chalk he might well have been correct, as I have found only the pentagonal form in the various zones down to *M. cor-testudinarium*, in which it occasionally appears, but in the Trimmingham Chalk it is often tetragonal, and in some specimens passes from the one form to the other.

Dr. Rowe may be right in saying that *Pentacrinus Agassizi* and *Broumi* are very common at Norwich and Sheringham, but I confess I am much surprised at the statement, for I have not found a specimen of either form at either locality, and I have spent much time on the chalk around Sheringham, though comparatively little on that around Norwich.

B. *Chalk between Cromer and Weybourne.*

SPONGIDA.

Porosphæra globularis, Phill. (very large).
Ventriculites impressus, T. Smith.
V. radiatus, T. Smith.

ACTINOZOA.

Asogaster cretacea, Lonsd.
Stephanophyllia Michelini, Lonsd. (common).
Trochosmilia (*laxa*?).

ECHINODERMATA.

Bourgueticrinus (joints, including one variety very typical at Trimmingham).
Cardiaster sp.
Cidaris.
Caphosoma (*Königi*?).
Echinoconus vulgaris, Röm.
Echinocorys vulgaris, Breyn.
Goniaster (ossicles).
Micraster cor-anguinum, Klein (common).

VERMES.

Serpula capillacea, Sow.
S. canteriata, Hag.
S. carinella (?), Sow.
S. difformis (?), Dix.
S. fluctuata, S. Woodw.
Serpula granulata, Sow.
S. gordialis, Schloth.
S. lituitis, Defr.
S. plexus, Sow.

CIRRHIPEDIA.

Brachylepas cretacea, H. Woodw. — *Scalpellum maximum*, Sow.
Pollicipes glaber, Röm.

POLYZOA.

Homalostega paronia, Hag. — *Pachydera grandis*, Mares.
Membranipora clathrata, Reuss. — *Porina filograna*, Goldf.
Many others of (at present) unknown zonal significance.

BRACHIOPODA.

Crania Egnabergensis, Retz. — *Terebratula carnea*, Sow.
C. Parisiensis, Defr. — *T. obesa*, Sow.
Magas pumilus, Sow. (very common). — *T. sexradiata*, Sow.
Rhynchonella limbata, Schloth. — *Terebratulina striata*, Wahl.
Rh. plicatilis, Sow. — *Thecidium Wetherelli*, Morris.
Rh. Reedensis, Eth.

LAMELLIBRANCHIATA.

Acicula cærulescens, Nilss. — *Pecten pulchellus*, Nilss.
Inoceramus sp. — *P. quinquecostatus*, Sow.
Lima granulata, Nilss. — *P. undulatus*, Nilss.
L. pectinata, D'Orb. — *Plicatula sigillina*, S. P. Woodw.
Ostrea canaliculata, Sow. — *Spondylus Dutempleanus*, D'Orb.
O. inæquicostata (?), S. Woodw. — *S. latus*, Sow.
O. vesicularis, Lam. — *S. spinosus*, Sow.
Pecten cretosus, Defr.

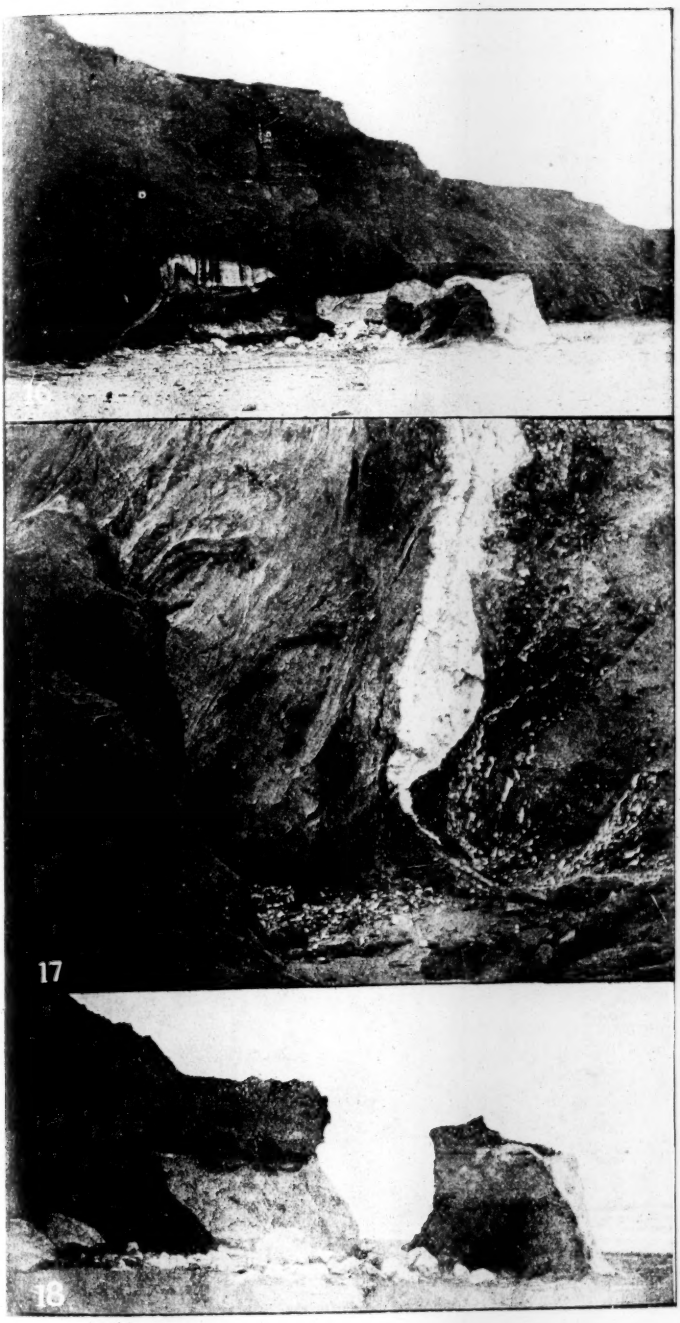
CEPHALOPODA.

Aptychus rugosus, Sharpe. — *Belemnitella mucronata*, Schloth.

PISCES.

Enchodus sp.

It is perhaps desirable to mention that these fossils come mainly from the western part of this chalk, i.e. about Sheringham and Weybourne. It may be partly owing to the greater facilities for collecting offered by the cliff exposures near Weybourne, but I have no doubt that it is also due to a genuine increase in the abundance of fossils as we get away from Cromer, where the chalk is wonderfully barren. Travelling in this direction, we are, according to Mr. Reid, passing from newer to older chalk, but I have great doubts about this. The only argument he adduces to support this view is that the dip of the chalk in the cliffs near Weybourne is to the east, and may be assumed to continue all the way (there certainly does not appear to be any traceable dip in any direction in the chalk on the foreshore). I have always doubted the existence of this steady eastward dip, and when in 1903 the chalk near Weybourne was exceptionally well exposed after a storm I studied it very carefully. I was able to trace the lines of flint very minutely, and I was absolutely convinced that for nearly three-quarters of a mile from Weybourne Gap the lines of flint are dipping steadily to the west. I have also observed indications that there is a syncline at West Runton, and not very far away a chance hole in the chalk with vertical sides showed a section across a flint line apparently lying in a small anticlinal. I am therefore more inclined to regard this chalk as, at any rate, undulating, if not actually dipping westward on the whole. The fossils of the chalk around Weybourne show a tendency towards the Trimmingham fauna, and it would be remarkable if between that chalk and the Trimmingham Chalk there really lay the very unfossiliferous chalk nearer Cromer.



Views of the Trimmingham Chalk Bluffs, Norfolk Coast.

(To illustrate Mr. R. M. Brydone's paper.)

An Appendix will follow, later on, with figures and descriptions of the Cirripedia and Polyzoa.—R. M. B.

EXPLANATION OF PLATES.

Plate VIII.

Fig. 13.—North Bluff, seaward aspect: May, 1905.
,, 14.—North Bluff, seaward aspect, showing (but only faintly, owing to shadow) the chalk roof over the clay pinnacle.
,, 15.—October 2nd, 1905, showing the aspect from the head of the south bay the day after the chalk roof was broken through.

Plate IX.

Fig. 16.—October 2nd, 1905. South bay.
,, 17.—October 2nd, 1905.
,, 18.—October 16th, 1905.

VII.—A Method of Classifying Igneous Rocks according to their Chemical Composition.

By Dr. Hugh Warth.

(WITH A FOLDING TABLE.)

THE chemical classification of igneous rocks is rendered difficult by the large number of substances which are present in them. H. S. Washington, who based his system of classification upon the composition of standard rock-forming minerals, found it necessary in his great work[1] to divide his 2,880 rocks into no less than 167 final groups in order to ensure a close proximity between the rocks within each group.

The number of rocks in any system of classification must rise so much more rapidly the greater the proximity of the individual rocks to each other. In the case of only a single constituent the deviation of individual rocks from the group average is inversely proportional to the number of groups. A similar law prevails when several constituents are considered at the same time, as will be shown in the following.

Five hundred rock analyses were selected at random for the purpose of classification. The average composition of this whole assembly of rocks was then calculated, and the mean deviation of the several substances was found by deducting the percentage of each substance present from the mean percentage of this substance in the five hundred rocks.

The differences obtained for all the rocks, positive as well as negative, were then added together, and the sum-total divided by 500 gave the mean deviation of each substance. It requires to be noted, however, that for the present purpose some of the substances were taken two and two together, and their combined deviations were thus ascertained. The following is the result:—

500 Rocks.	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O
Average composition ...	57·0	15·5	3·9	3·9	4·8	5·8	3·6	2·9
Mean deviation	± 9·6	3·0	4·0		7·0		2·6	

[1] H. S. Washington, "Chemical Analyses of Igneous Rocks"; Washington Government Printing Office, 1903.

The total mean deviation is 26·2. In the above average we omitted ·5 per cent. TiO_2, ·2 per cent. P_2O_5, 1·9 per cent. H_2O, because these substances are excluded from the partition scheme.

The next step that may now be taken is as follows:—Divide the 500 rocks into two kinds, those which have less than the average of 57·0 per cent. silica and those which have more. I find that 265 rocks belong to the former with an average of 48·3 per cent. silica, and 235 rocks to the latter class with an average of 66·9 per cent. silica. The mean total deviation within these two groups has now been reduced from 26·2 to 17·1. Dividing these two groups once more according to their silica percentage, one obtains four groups with respectively 43·4, 52·5, 61·0, and 72·7 per cent. silica. The average deviation is now 13·2, or about one-half of the original. It happens that these four groups nearly coincide with the old-established division of rocks into acid, intermediate, basic, and ultra-basic rocks, and it is noteworthy that this very simple classification reduces the deviation already to one-half of its original amount.

As will be seen later on, it needs four times as many groups to reduce the mean total deviation to approximately one-third of the original deviation, and H. S. Washington's elaborate system reduces it at the most to one-fourth.

If the above-mentioned fourfold grouping of the 500 rocks be continued by now partitioning according to the percentage of alumina, eight groups are obtained with a deviation of 10·9.

Further partition into 16 groups yielded different results according to the choice and order of substances. The following deviations are obtained:—

Order of Substances.	Total Deviation.
$Fe_2O_3 + FeO$, $MgO + CaO$, Al_2O_3, $Na_2O + K_2O$ ...	10·5
$Fe_2O_3 + FeO$, Al_2O_3, $MgO + CaO$, $Na_2O + K_2O$ ...	10·4
SiO_2, $Fe_2O_3 + FeO$, $MgO + CaO$, $Na_2O + K_2O$ ...	10·2
SiO_2, Al_2O_3, $MgO + CaO$, $Na_2O + K_2O$	9·7
Four bases, three last bases, two last bases, $Na_2O + K_2O$ ...	9·5
All four sets of bases, omitting successively the following:	
Al_2O_3, $Fe_2O_3 + FeO$, $MgO + CaO$, $Na_2O + K_2O$ ...	9·0

This last method of grouping, which gave the best result, is herewith adopted for use.

Further partition into 32 groups reduced the total deviation as follows:—

Order of Substances.	Total Deviation.
$Fe_2O_3 + FeO$, Al_2O_3, $MgO + CaO$, $Na_2O + K_2O$, all bases	7·7
All bases, successively minus the following:	
Al_2O_3, $Fe_2O_3 + FeO$, $MgO + CaO$, $Na_2O + K_2O$, and finally all bases (with a few modifications)	7·4

The same principle might be applied for the purpose of still further subdivision. With 128 groups it would be possible to treat all the seven bases separately. It would, however, be necessary to employ a larger number of analyses to secure accuracy.

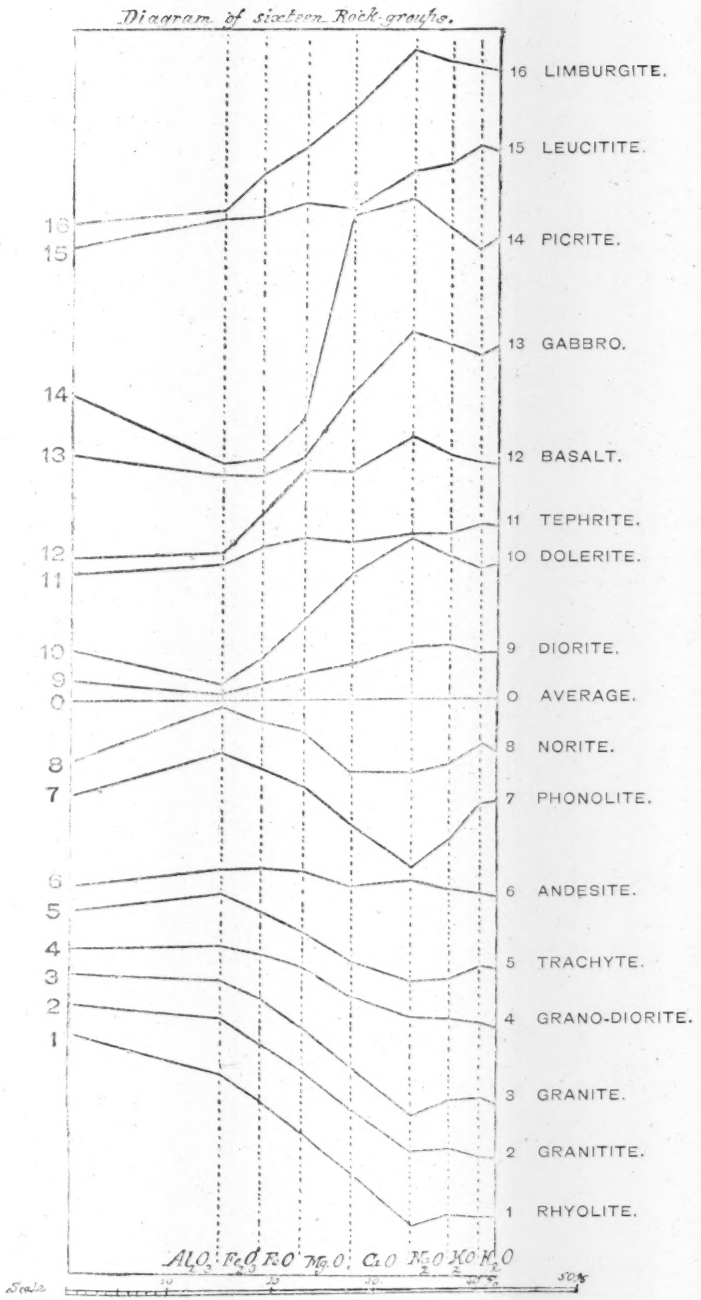


Diagram of sixteen Rock-groups.
16 LIMBURGITE.
15 LEUCITITE.
14 PICRITE.
13 GABBRO.
12 BASALT.
11 TEPHRITE.
10 DOLERITE.
9 DIORITE.
0 AVERAGE.
8 NORITE.
7 PHONOLITE.
6 ANDESITE.
5 TRACHYTE.
4 GRANO-DIORITE.
3 GRANITE.
2 GRANITITE.
1 RHYOLITE.
16
15
14
13
12
11
10
9
0
8
7
6
5
4
3
2
1
Al_2O_3 Fe_2O_3 FeO MgO CaO Na_2O KO H_2O
Scale
10
20
30
50%

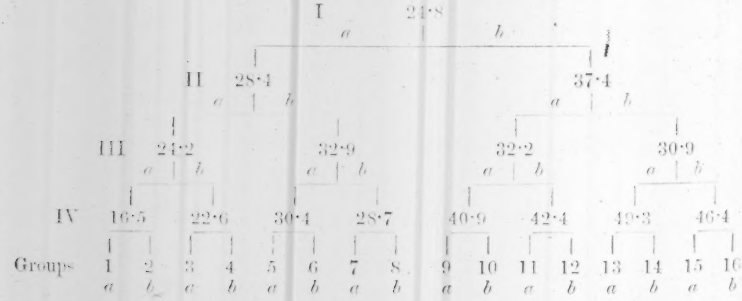
My present object is to employ a moderate number of divisions, and for this purpose 16 groups appear to answer best. The combination of similar bases has enabled me to simplify the system. The individual bases maintain generally a correct proportion, and when they do not the bases of a pair may easily be understood to replace each other (see Table II).

The separate table (Table I) shows the average compositions of the 16 groups which are here used. There is added for each group the name of a typical rock which occurs in the group. To facilitate the discussion of the table I also add a Diagram (p. 133) which requires some explanation. The vertical bands of the diagram are of such widths that they represent by the scale the average percentage of the seven basic oxides and of water.

If a line be drawn from point *O* of the diagram inclined at 45°, and if we then measure from the intersection of that line with the right margin of each band along that margin the sums of the bases Al_2O_3, $Al_2O_3 + Fe_2O_3$, $Al_2O_3 + Fe_2O_3 + FeO$, etc., etc., we obtain a straight horizontal line which stands for the average of 500 rocks. If we apply the corresponding numbers for any one of the rock groups we obtain the curves shown on the diagram. The acid rocks have descending curves, the basic rocks have ascending ones. The descent of a portion of any curve implies that the proportion of the respective bases is below the average, and *vice versâ*. Horizontal portions occur in a curve whenever the respective components are equal to the average of the 500 rocks.

In order to illustrate further the degree of proximity within the groups of rocks I herewith give an example of an entire group (Table II). This group No. 9, *b a a a*, has a mean total deviation of 9·4, which is very close to the average of all the groups and will therefore give a fair idea. Other more acid groups would show a greater proximity, whilst the most basic groups would be most divergent, as may be seen on the above-mentioned Table I.

Scheme of Division into 16 Rock-Groups.



Although the above system is only based upon 500 selected rocks, any number of others may be incorporated by following the same standard averages. In the separate Table I, the averages are given which served for the establishment of the 16 groups. These same

[Note to Binder.]—To be inserted by Binder at this edge.]

TABLE I.—AVERAGE COMPOSITION OF THE SIXTEEN ADOPTED ROCK-GROUPS.

Group.	Formula. I	II	III	IV	SiO_2	TiO_2	P_2O_5	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	Total.	Rocks in each Group.	Typical Rock Name.	Total Deviation.
1	*a*	*a*	*a*	*a*	76·4	·1		11·4	1·2	·7	·4	·8	3·3	3·9	1·8	100·0	35	Rhyolite.	6·4
2	*a*	*a*	*a*	*b*	73·4	·1		14·0	1·4	1·0	·8	1·8	2·7	3·2	1·5	99·9	26	Granitite.	5·7
3	*a*	*a*	*b*	*a*	70·6	·1		14·9	2·0	1·0	·4	1·1	3·8	4·6	1·2	99·7	41	Granite.	5·4
4	*a*	*a*	*b*	*b*	65·6	·3	·1	15·6	3·0	2·8	1·6	3·6	3·4	2·6	1·5	100·1	29	Grano-diorite.	7·7
5	*a*	*b*	*a*	*a*	63·2	·3	·1	17·3	2·3	1·8	1·6	3·6	4·9	3·3	1·7	100·1	37	Trachyte.	6·3
6	*a*	*b*	*a*	*b*	58·5	·3	·2	17·4	3·9	3·4	3·3	6·2	3·3	2·0	1·6	100·1	37	Andesite.	6·3
7	*a*	*b*	*b*	*a*	58·4	·2		19·9	2·2	2·1	·6	1·6	7·1	5·8	2·2	100·1	39	Phonolite.	6·4
8	*a*	*b*	*b*	*b*	55·4	·5	·2	20·8	3·1	3·1	1·7	4·5	5·5	3·7	1·4	100·2	19	Norite.	12·9
9	*b*	*a*	*a*	*a*	54·0	·8	·5	14·1	4·9	4·7	5·6	7·6	3·0	2·9	1·9	100·0	55	Diorite.	9·4
10	*b*	*a*	*a*	*b*	48·6	1·1	·2	12·3	5·9	8·1	9·4	9·3	2·3	·9	2·1	100·2	37	Dolerite.	12·3
11	*b*	*a*	*b*	*a*	52·4	·5	·2	16·4	5·5	5·8	3·4	6·5	4·4	2·9	2·0	100·0	25	Tephrite.	10·1
12	*b*	*a*	*b*	*b*	46·9	1·4	·2	16·2	7·4	8·2	5·0	9·0	2·7	1·3	1·6	99·9	33	Basalt.	9·4
13	*b*	*b*	*a*	*a*	46·1	·8	·2	13·5	3·9	5·4	11·3	11·9	2·4	1·8	2·6	99·9	26	Gabbro.	12·4
14	*b*	*b*	*a*	*b*	41·3	·7	·1	8·5	4·4	7·6	25·2	7·4	1·0	·4	3·3	99·9	23	Pierite.	14·8
15	*b*	*b*	*b*	*a*	47·3	·6	·3	18·5	4·0	5·2	4·5	9·4	5·1	3·6	1·6	100·1	29	Leucitite.	10·7
16	*b*	*b*	*b*	*b*	41·4	·9	·4	16·9	7·5	6·3	8·7	11·9	3·0	1·6	1·7	100·3	29	Limburgite.	13·9
Total average				...	57·0	·5	·2	15·5	3·9	3·9	4·8	5·8	3·6	2·9	1·9	100·0	500		
Mean deviation				...	± 2·3		...	± 1·8	± (1·6)		± (1·9)		± (1·4)		...	...	...	...	9·0

TABLE II.—GROUP 9 OF THE ADOPTED SERIES OF SIXTEEN ROCK-GROUPS.

	b	*a*	*a*	*a*
	I	II	III	IV
	24·8	37·4	32·2	40·9
	+	−	−	−

Total bases minus Al_2O_3, $(Fe_2O_3 + FeO)$, $(MgO + CaO)$, $(Na_2O + K_2O)$.

SiO_2	TiO_2	P_2O_5	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O	Total.	Author.	Rock Name.	Locality.
68·8	...		5·9	5·8	5·3	·1	2·1	7·5	4·3	...	100·0	H. S. Washington, p. 220.	Pantellerite.	Pantellaria.
58·2	...		14·9	8·3		3·0	8·0	3·3	3·5	·8	100·0	N. Jahrbuch, 1903.	Trachyte.	Mount Cimina.
57·6		·8	14·7	8·6		5·0	7·5	3·5	1·9	·8	100·3	H. S. Washington, p. 424.	Ol. pyr. andesite.	Lipari Islands.
57·4	...		16·9	2·5	5·2	5·5	7·3	3·3	1·9	·8	100·7	,, p. 274.	Pyrox. porphyrite.	Yellowstone Park.
57·4	...		15·7	2·1	5·2	8·8	4·9	3·1	1·5	·7	99·9	,, p. 276.	Basalt.	California.
57·3	·6	·2	16·4	1·7	4·8	6·7	7·7	3·0	1·6	·4	100·4	,, p. 278.	Quartz basalt.	California.
57·3	...		10·9	2·0	6·0	4·6	8·6	1·5	7·6	1·5	100·0	N. Jahrbuch, 1903.	Mimette.	Bohemia.
56·2		·3	16·1	4·9	4·4	4·6	7·0	3·0	2·4	1·0	99·9	H. S. Washington, p. 276.	Hyp. andesite.	Colorado.
56·0	·7		12·5	·5	15·9	6·1	4·2	2·0	·7	·7	99·3	,, p. 420.	Hyp. andesite.	Spitzbergen.
55·8	1·1	·2	17·1	4·1	3·8	5·1	7·4	2·9	1·7	1·3	100·4	,, p. 232.	Pyr. andesite.	National Park.
55·4	...		16·8	9·3		5·2	7·6	3·6	1·4	1·2	100·5	,, p. 408.	Augite diorite.	Hungary.
54·6	·6		12·1	1·8	5·1	11·9	7·7	2·4	1·0	2·6	100·0	,, p. 320.	Quartz diorite.	California.
54·4	·3	·3	14·3	6·3	4·2	5·9	7·5	3·4	2·2	1·2	100·0	,, p. 278.	Diorite gneiss.	British Guiana.
54·3	...		10·1	7·1	5·8	6·5	8·9	4·1	2·2	·6	99·6	Cole's handbook.	Olivine dolerite.	Hessen.
54·2	·9	·5	14·4	2·3	4·8	7·7	7·0	2·3	3·3	2·6	100·1	H. S. Washington, p. 268.	Ol. weisselbergite.	Prussia.
54·2	2·7	1·6	10·2	3·5	·7	6·6	5·0	1·2	11·9	2·1	100·2	,, p. 312.	Orendite.	Wyoming.
54·1	...		15·0	4·1	5·1	7·3	7·7	2·0	3·5	1·5	100·3	Hatch, textbook.	Diorite.	Benan.
53·8		2·0	15·8	6·9	4·3	5·5	7·7	3·0	·7	·8	100·5	N. Jahrbuch, 1904.	Dolerite.	Oberofleiden.
53·6		·9	14·2	1·5	8·1	7·1	8·5	1·8	2·0	2·6	100·3	H. S. Washington, p. 328.	Andesite.	Tuscany.
53·0		·6	13·1	8·2	2·5	5·2	10·6	3·3	2·0	2·2	100·7	,, p. 324.	Basalt.	Volcano.
52·8	2·1	·5	12·5	9·1	4·0	4·5	8·1	2·6	2·4	1·0	99·6	N. Jahrbuch, 1904.	Dolerite.	Oberofleiden.
52·5	...		12·1	3·5	5·2	9·9	9·7	2·8	2·2	2·1	100·0	Cole's handbook.	Diorite.	
52·3	·6	·6	14·9	3·5	3·7	5·8	6·3	2·9	3·8	(5·3)	99·9	H. S. Washington, p. 270.	Kersantite.	Thüringerwald.
52·2	1·4	·5	14·6	10·8	3·2	5·0	8·7	1·8	·6	·3	99·1	N. Jahrbuch, 1904.	Dolerite.	Oberofleiden.
52·2	2·1	·1	12·2	10·1	2·9	5·5	7·1	3·8	2·2	1·1	99·3	,, 1904.	Dolerite.	Oberofleiden.
51·3	1·4		15·5	3·2	7·1	4·4	9·2	3·8	1·2	(2·9)	100·0	Pamphlets, 1871.	Anamesite.	Dieteshcim.
51·2	1·0	·5	16·1	4·1	4·7	4·8	7·9	3·0	3·5	2·9	99·9	H. S. Washington, p. 266.	Aug. andesite.	National Park.
51·2	2·4	·3	14·1	4·6	8·9	4·4	8·3	2·6	1·3	1·6	99·7	Cole's handbook.	Dolerite.	Durham.
51·0	1·8	·7	14·5	4·2	4·4	8·2	5·1	1·8	7·2	1·0	99·9	H. S. Washington, p. 254.	Durbachite.	Black Forest.
51·0	·7	·5	15·6	8·5	1·4	5·2	6·5	3·4	3·1	3·9	99·8	,, p. 274.	Hornbl. basalt?	National Park.
50·3	1·0	·5	15·9	8·2	1·5	4·7	7·9	3·0	3·5	3·8	100·3	,, p. 268.	Gabbro porphyry.	Yellowstone Park.
49·8	2·7	·7	15·3		7·7	6·6	7·2	2·7	4·4	4·0	101·1	,, p. 418.	Mica andesite.	New Mexico.
49·6	·7	6·0	9·6	5·6	5·2	1·3	13·9	4·9	3·2	·4	100·3	,, p. 312.	Pyr. ap. syenite.	Montana.
49·0	2·8		15·3	2·6	8·2	4·9	8·2	2·5	2·6	3·3	99·4	Hatch, textbook.	Dolerite.	Rowley.
48·3	1·0	·2	17·1	1·9	4·9	3·1	9·8	3·1	2·4	8·5	100·2	H. S. Washington, p. 445.	Melaphyre.	Harz.
54·0	·8	·5	14·1	4·9	4·7	5·6	7·6	3·0	2·9	1·9	100·0	...	Diorite.	
± 2·6	...		± 1·9	± 1·9		± 1·5		± 1·5		...	± 9·4			

TWO TABLES TO ILLUSTRATE DR. HUGH WARTH'S ARTICLE "ON A METHOD OF CLASSIFYING IGNEOUS ROCKS ACCORDING TO THEIR CHEMICAL COMPOSITION."—GEOL. MAG., MARCH, 1906, NO. 501.

averages serve to find the group to which any other igneous rock belongs. The following two examples will illustrate this:—

No. 1, a specimen of Elvan from Cornwall, recorded in Cole's handbook.

No. 2, a rock named Teschenite from Cape Verde, recorded by H. S. Washington, p. 352.

	SiO_2	Al_2O_3	Fe_2O_3	FeO	MgO	CaO	Na_2O	K_2O	H_2O
No. 1 ...	71·4	15·4	·3	2·3	·2	·5	2·8	5·5	1·7
No. 2 ...	39·6	17·0	6·6	9·3	6·7	10·6	6·0	3·1	1·3

First calculate the four values I, II, III, IV, which represent the total of the seven bases (or four sets of bases) minus respectively Al_2O_3, $Fe_2O_3 + FeO$, $MgO + CaO$, $Na_2O + K_2O$. The values are as follows:—

	I.	II.	III.	IV.
No. 1 ...	11·6	24·4	26·3	18·7
No. 2 ...	42·3	43·4	42·0	50·2

Following the scheme, p. 134, we find that sum I of example No. 1 is below the average of 24·8, and is therefore to be marked as (*a*). For comparison with II the reader must now take the left-hand value of II = 28·4, and this gives again (*a*). For comparison with III we have thus again the left-hand value III = 24·2. We now have an excess and letter (*b*). The fourth letter is again (*a*), because 18·7 is smaller than 22·6. The entire formula for rock No. 1 is therefore (*a a b a*), group 3 (granite) of separate Table I.

Sample No. 2, compared in the same way with the scheme, p. 134, is found in all four cases to exceed the corresponding numbers of the scheme; the formula is therefore (*b b b b*), group 16 of Table I.

REVIEWS.

I.—Catalogue of the Fossil Plants of the Glossopteris Flora in the Department of Geology, British Museum (Natural History); being a monograph of the Permo-Carboniferous Flora of India and the Southern Hemisphere. By E. A. Newell Arber, M.A., F.L.S., F.G.S., Trinity College, Cambridge, University Demonstrator in Palæobotany. (London, 1905.)

THE present Keeper of the Geological Department of the British Museum has continued the wise policy of his predecessor in encouraging the production of comprehensive accounts of the fossil floras represented in the National Collection. Mr. Arber's volume supplies geologists and botanists with an excellent summary of the present state of our knowledge in regard to the Glossopteris Flora, and includes concise descriptions of the abundant material in the Fossil Plant Gallery. The excellent illustrations by Miss G. M. Woodward add considerably to the value of the work.

It is a striking fact that the six volumes dealing with Fossil Plants in the British Museum which have so far been published are

written by men who are not members of the Museum Staff. By sanctioning the expenditure entailed in the production of these catalogues the Trustees have recognised the importance of the palæobotanical collections; but it is to be regretted that this branch of palæobotany has not been placed under the care of an expert assistant. This is not the place for an expression of opinion as to the best method of dealing with fossil plants in a Natural History Museum, but it is perhaps not unreasonable to suggest that the subject of palæobotany is worthy of recognition as an important branch of Natural Science which should be under the charge of a specialist competent to arrange, describe, and extend the collections under his care.

Mr. Arber's Introduction may be described as the best account which has so far been given of the botanical affinities and distribution of the Glossopteris Flora. The widely scattered literature on the Permo-Carboniferous vegetation from South America, South Africa, India, and Australia is summarised in a comprehensive Historical Sketch. In the descriptive portion of the volume the author has added considerably to the value of the work by including certain types which are not represented in the Museum. Under the Thallophyta are included the somewhat problematical fossils ascribed by Bertrand and Renault to the Algæ. Under the Equisetales the genera *Schizoneura* and *Phyllotheca* are fully described so far as the material permits, but in regard to the representatives of the Equisetales, as in the case of nearly all the fossil plants from the Glossopteris-bearing strata, there is a surprising dearth of material which throws light on the nature of the reproductive organs or on anatomical structure.

In the section dealing with ferns Mr. Arber contributes a carefully drawn up synopsis of the species of *Glossopteris* which cannot fail to be of value to students of this flora. Everyone with any knowledge of recent ferns admits the impossibility of attempting to recognise true specific characters in the numerous forms of frond and in the slight differences in venation characters; but some system, though an admittedly artificial one, is necessary as a working scheme for descriptive and cataloguing purposes. The account of the fructification of *Glossopteris*, based on the results of the author's original observations, is particularly interesting; supposed fertile fronds of this genus have often been described, but we have now for the first time a description of undoubted reproductive organs. Among the Gymnosperms are included several genera of more or less doubtful position, but it is refreshing to find one set of petrified specimens—referred to *Dadoxylon*—exhibiting anatomical characters in a good state of preservation. There is little doubt that the long strap-like leaves which it has been customary to refer to *Noeggerathiopsis* are generically identical with the European *Cordaites*. Mr. Arber, though retaining the former name, admits the close alliance of the northern and southern forms.

A perusal of the bibliography at the end of the volume affords some idea of the labour involved in monographing the Glossopteris

Flora. The task has been difficult. The imperfect nature of the specimens has rendered accurate diagnosis and determination impossible in many cases, but the author has faced the difficulties in a spirit of scientific caution, and there has been no attempt to overestimate the significance of unimportant characters. The volume before us will be thoroughly appreciated by residents in South Africa, Australia, and other countries where the Glossopteris Flora occurs, and we may confidently look forward to the discovery of better specimens which will afford the means of placing on a firmer basis of botanical knowledge the vegetation of Gondwana Land.

II.—A Guide to the Fossil Reptiles, Amphibians, and Fishes in the Department of Geology and Palæontology, British Museum (Natural History), Cromwell Road, London, S.W. Eighth edition (entirely re-written), 1905. 8vo; pp. 110, with 8 plates and 116 figures in the text. (Price 6*d.*)

(PLATE XII.)

THE progress of biological science has been so great within the last fifty years that the barrier which once divided the two branches of study into fossil and recent animals has been swept away, and we find the student of zoology quite eager to learn all he can about those ancient forms of life, now long since extinct, and to trace out their relationship with their living descendants.

It thus happens that on entering the Geological Department we see the modern Indian Elephant installed close to the American Mastodon and the European Mammoth, while near by are the more ancient ancestral forms of *Palæomastodon*, *Mœritherium*, etc., from Egypt, together with the *Dinotherium* and the existing African Elephant to 'round up' the story of the Proboscidea.

On the modern Zoological side advances have also been made towards an *entente cordiale* between the recent and fossil Reptilia, and we find the centre of the gallery occupied by the newly acquired skeleton of *Diplodocus Carnegiei*, a huge Dinosaurian land reptile, 80 feet in length, from the Upper Jurassic strata of Wyoming Territory, U.S.A.,[1] surrounded by a court of recent Crocodiles, Tortoises, Snakes, and Lizards, whilst pictures and casts of various fossil forms are shown in the cases with their recent congeners.

These arrangements, of course, partake of compromise, but it would be next to impossible frequently to change the order of such vast collections as are preserved in the National Museum; the business is costly in the extreme, and the amount of labour involved simply stupendous. Professor Sir Wm. Flower, the late Director, commenced a rearrangement of a part of the collections, assisted by Mr. Lydekker, one of the most active and energetic of zoologists; but Flower died in 1899, and although Lydekker has continued his labours in association with Professor Ray Lankester, the present Director, the vast work of reorganizing the Zoological Galleries is still in progress.

[1] See Geol. Mag., December, 1905, p. 576, Pl. XXV.

Dealing only with extinct forms (save where a few living representatives have been introduced), the Keeper of the Department of Geology and Palæontology, Dr. Arthur Smith Woodward, and his predecessor, have devoted their entire energies during twenty-six years, since the removal from Bloomsbury, in bringing the great collections into order, and in the preparation of catalogues and guidebooks, of which quite a large number have been published.

Although the staff at the Keeper's command is but small, it has been most efficient in carrying on the general work, whilst a dozen or more scientific experts, specially engaged, have taken up the task of naming or arranging and cataloguing various groups to which each specialist had devoted himself. This explains the very excellent and 'up-to-date' appearance of the palæontological collections generally, both in the matter of arrangement and labelling, to which especial attention has been paid.

The Guide which is now before us—an entirely new edition—contains an account of the Reptiles, Amphibians, and Fishes which occupy 5 Galleries; the Reptilia taking up 54 table and wall-cases, the footprints of Reptiles, etc., 3 wall-cases, the Amphibia 4 cases, and the Fishes an entire Gallery, fitted up with 61 wall and table-cases. Four catalogues appeared between 1888 and 1890, by Mr. Lydekker, on the Fossil Reptilia and Amphibia, comprising over 1,200 pages of descriptions and 273 woodcuts in the text; but since then the collection has nearly doubled itself in extent.

The Guide now issued is so splendidly illustrated that it brings the account of this part of the Geological galleries well up to date. Some idea of the excellence of the figures may be gained by reference to the accompanying Plate XII, giving a view of two skulls of *Miolania*, the remarkable horned tortoise, one species of which was found in the so-called Cretaceous of Patagonia, the other in the Pleistocene of Queensland, Australia. Another illustration given is of *Diplodocus Carnegiei* (see GEOL. MAG., December, 1905, Plate XXV).

Among further striking and important additions recently made to the fossil Reptiles on the eastern side of the building may be mentioned the setting up of the limbs and tail of a Dinosaurian land reptile (*Cetiosaurus Leedsii*) discovered by Mr. Alfred N. Leeds in the Oxford Clay near Peterborough, of which a page-plate is given in the Guide. It was a beast as large as the *Diplodocus*, and closely allied to it.

Another striking object is the skeleton of a huge toothless flying reptile (*Pteranodon occidentalis*) from the Upper Cretaceous of Kansas, U.S.A. The bones, so far as obtained, are mounted on a life-size picture of the complete skeleton in wall-case 2, at the east end of the gallery. The total expanse of the wings is about eighteen feet. The great crest on the back of the skull may have served for the attachment of some of the muscles which moved these vast wings.

The skeleton of *Pariasaurus*, a huge Anomodont reptile from the Karoo Formation of Cape Colony, discovered by Professor H. G. Seeley; the articulated skeletons of two Plesiosaurs, reconstructed

A

B

Skulls of two species of a Horned Tortoise (*Miolania*).

A. *Miolania argentina*, from the supposed Cretaceous of Chubut, Patagonia.
B. *Miolania Oweni*, from the Pleistocene of Queensland, Australia.

from the actual bones out of the Oxford Clay near Peterborough, obtained by Mr. A. N. Leeds; the fine series of Ichthyosaurs and Plesiosaurs on the walls; the reproduction of the Bernissart *Iguanodon* from Belgium, in the centre of the gallery; and lastly, the reconstructed skeleton of *Polacanthus Foxii*, an armed reptile from the Wealden of the Isle of Wight (see GEOL. MAG., June, 1905, p. 242, Plate XII), make up a most attractive and striking display of Mesozoic Reptilian life.

The Fish Gallery has always been a magnificent exhibition, and is still unsurpassed by any other in the world. In addition to all his other work Dr. Arthur Smith Woodward has spent 13 years in the production of four large volumes on the series of Fossil Fishes, covering 2,393 pages of text, with 138 text illustrations and 70 plates, including a large number of very beautiful outline restorations of special genera. The latest wonder is a tail of the gigantic *Leedsia problematica*, from the Oxford Clay of Peterborough, mounted on the east wall between cases 13 and 14. It has a span of 9 feet, and probably represented a fish 30 feet in length! The series of remains of giant armoured Devonian fishes from Ohio of the genus *Dinichthys* deserve to be specially mentioned, and the *nearly complete* examples of sharks, *Cladoselache*, from Cleveland, Ohio (also of Devonian age), some of which were 5 to 6 feet in length, showing the jaws with teeth, the paired fins and tail, with the outline of the body.

Another group of curious Palæozoic sharks, with a coiled up series of teeth (to which the genus *Edestus Davisii* belongs, see figure and description, GEOL. MAG., 1886, p. 1, Plate I), has been discovered by Professor Karpinsky in the Permo-Carboniferous of Perm, Russia, having a coil of teeth so symmetrically arranged as to present a close resemblance to an Ammonite or other discoidally coiled fossil shell.

We wish that space permitted a longer notice, for the collections here described and illustrated so profusely in this little Guide, deserve to be even more widely known than they are; but such excellent handbooks, at so small a price, are sure to attract students; even the ordinary visitor, more bent upon pleasure than instruction, cannot fail to be delighted and amused and take away with the book some grains of knowledge. But it is especially for the young that these beautiful guidebooks are intended, and we hope the pictures may prove an attractive bait to many boys and girls who may thus turn out to be the geologists of the future.

REPORTS AND PROCEEDINGS.

GEOLOGICAL SOCIETY OF LONDON.

I.—January 24th, 1906.—J. E. Marr, Sc.D., F.R.S., President, in the Chair. The following communications were read:—

1. "On the Igneous and Associated Sedimentary Rocks of Llangynog (Caermarthenshire)." By T. Crosbee Cantrill, B.Sc., and Herbert Henry Thomas, M.A., F.G.S.

from the actual bones out of the Oxford Clay near Peterborough, obtained by Mr. A. N. Leeds; the fine series of Ichthyosaurs and Plesiosaurs on the walls; the reproduction of the Bernissart *Iguanodon* from Belgium, in the centre of the gallery; and lastly, the reconstructed skeleton of *Polacanthus Foxii*, an armed reptile from the Wealden of the Isle of Wight (see GEOL. MAG., June, 1905, p. 242, Plate XII), make up a most attractive and striking display of Mesozoic Reptilian life.

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The sedimentary rocks associated with the various igneous masses comprise the following :—

Lower Old Red Sandstone.	Red marls and sandstones, with cornstones and conglomerates at the base.
Ordovician (Arenig).	*Didymograptus bifidus* Beds. Blue-black shales, with one or more thick bands of grit towards the base.
	Tetragraptus Beds. Black and buff shales with thin grit bands; thick bands of ashy grits and conglomerates towards the base.

These rocks are described in detail. They occur in two main anticlines, overfolded, and complicated by thrusts which cut out a great part of the intervening syncline. They are covered unconformably by the lower beds of the Old Red Sandstone. The igneous rocks occur in three well-defined areas, which belong to the same petrographical province, near Coomb, at Capel Bethesda, and at Lambstone. Both interbedded and intrusive rocks are represented, and full petrographical descriptions of all types are given in the paper. The latter include diabases, and the large porphyry mass of Lambstone. The extrusive rocks have been determined to occur in the following order :—(1) augite-andesites; (2) rhyolites; and (3) augite-andesites, with some hornblende-andesite. The extrusive rocks are interbedded with fluxion breccias and with tuffs; they are associated with the lower members of the *Tetragraptus* Beds, and are consequently of Lower Arenig age; while the intrusive rocks have been injected into the extrusive rocks, and have also affected the *Tetragraptus* Beds, but at what date exactly it is impossible to say, except that it antedates the Old Red Sandstone. Much of the folding and faulting was accomplished before the Lower Old Red Sandstone was deposited, but certain faults involve this formation, and make it clear that there was an important later movement.

2. "The Buttermere and Ennerdale Granophyre." By Robert Heron Rastall, B.A., F.G.S. (Christ's College, Cambridge).

This paper embodies the results of field-mapping and microscopical study of the large mass of igneous rocks known, collectively, as the Buttermere and Ennerdale Granophyre. From the facts put forward it is concluded that the intrusion is an example of an acid magma, which has crystallized under the peculiar set of conditions that gives rise to a very perfect development of granophyric structure. These conditions are probably, to a certain extent, intermediate between those of plutonic and true hypabyssal rocks. The masses appear to be of the 'cedar-tree' laccolite type intrusive about the junction of the Skiddaw Slates and the Borrowdale rocks, but penetrating into the higher rocks. Besides the normal acidic rock, which comprises the bulk of the intrusions, there are some marginal patches of more basic character, showing obvious genetic relationship, and slightly earlier in point of time than the intrusion of the acidic rock. These basic forerunners afford evidence of differentiation of the magma before intrusion—an example of Professor Brögger's deep magmatic differentiation. Considered as a whole, the character of the magma shows closer affinity to the tonalite

group than to the true granites, although it is somewhat more acid than the majority of tonalites. The more basic types include dolerites, quartz-dolerites, and a rock type intermediate between quartz-dolerites and granophyres, for which no satisfactory name seems to exist. There is also a development of peculiar rock types as the result of the re-mixing of previously differentiated partial magmas of an acid and a basic character respectively. A study of the distribution of different types of granophyric structure shows a certain regularity of arrangement, and an attempt is made to reconcile these with known physical laws, especially with reference to eutectics; and it is concluded that the structure is the result of crystallization under conditions intermediate between those which produce typical plutonic and hypabyssal rocks.

II.—February 7th, 1906.—J. E. Marr, Sc.D., F.R.S., President, in the Chair. The following communications were read :—

1. "The Carboniferous Limestone (Avonian) of the Mendip Area (Somerset), with especial reference to the Palæontological Sequence." By Thomas Franklin Sibly, B.Sc., F.G.S.

The Avonian rocks are exposed in four main anticlinal forms or periclines—those of Black Down, North Hill, Pen Hill, and Beacon Hill; each of which has an approximately east-and-west trend and has Old Red Sandstone exposed in its core. The following is the zonal succession :—

	Zones.	Subzones and Horizons.	Feet.
Kidwellian.	*Dibunophyllum*	D_2. *Lonsdalia floriformis*. D_1. *Dibunophyllum* θ.	500
	Seminula	S_2. *Productus* aff. *Cora* mut. S_2. S_1. *P.* cf. *semireticulatus* mut. S_1.	720
Cleistonian.	*Syringothyris*	C. *S. cuspidata*.	550
	Zaphrentis	Z_2. *Z.* aff. *cornucopiæ*. Z_1. *Spirifer* aff. *clathratus*.	800
	Cleistopora	K_2. *Spiriferina* cf. *octoplicata*. K_1. *Productus hassus*. M. (*Modiola*-phase.)	450

In the present paper, the faunal sequence is discussed in detail, attention being confined almost entirely to the corals and brachiopods, which predominate throughout the series. The lithological character of each zone and subzone is treated briefly. The general stratigraphy of the area is briefly discussed, reference being made to the more important forms. Following this, the exposures examined are classified in zonal order, and tabulated under the zonal headings. The best exposures of each zone receive special attention.

A correlation with the Bristol area brings out the following more important points. The faunal succession is essentially similar in the two areas; and in both there is good ground for a twofold division into Clevedonian and Kidwellian stages, the line of separation being drawn at the top of the *Syringothyris* Zone. The Mendip area exhibits, however: (1) a great expansion in the thickness of the *Zaphrentis* and *Syringothyris* Zones; (2) a continuously fossiliferous sequence from the top of the *Zaphrentis* Zone to the base of the *Seminula* Zone, possessing a characteristic coral and brachiopod fauna; and (3) a relative acceleration of the coral fauna on the brachiopod fauna, exhibited in the *Zaphrentis* Zone.

The paper contains a detailed account of the Ebbor Rocks District, near Wells, and concludes with notes on certain corals and brachiopods included in the faunal lists, together with descriptions of some new species and mutations.

2. "The Igneous Rocks of the Eastern Mendips." By Professor Sidney Hugh Reynolds, M.A., F.G.S.

The igneous rocks associated with the Old Red Sandstone of the Mendips are exposed along the crest of the range from Beacon Hill on the west to near Downhead on the east, a distance of rather more than 2 miles. Hitherto they have always been regarded as intrusive, but the opening of some new excavations has shown that they are associated with a considerable thickness of tuffs, and are in all probability contemporaneous lava-flows.

The exposures show a division into three sections—those of Beacon Hill, Moon's Hill, and Downhead; and a large quarry has been opened in the trap in each section. The trap, which can be traced fairly continuously from one end of the area to the other, is very uniform in character, consisting (as already noted by Dr. Teall) of a non-amygdaloidal pyroxene-andesite, which usually contains augite in addition to enstatite. A fine section of tuff some 100 feet thick is seen lying with perfect conformity below the trap in the New Quarry near Stoke Lane; and an interesting little exposure of tuff, remarkable for the numerous rounded blocks of trap present, is seen in the excavation for the rifle-butts on Beacon Hill. The tuff here dips under the Old Red Sandstone to the north. Although the tuff is seen *in situ* only at the above two points, loose pieces have been met with at a number of other spots all along the southern outcrop of the trap, and point clearly to the occurrence of a continuous band underlying it.

Though no sedimentary rocks are seen in direct contact with those of the igneous series, outcrops of Old Red Sandstone completely surround the exposures of trap and tuff, and occur in such close relation to them as to leave little room for doubt that the igneous series is of Old Red Sandstone age. On the other hand, Silurian fossils were met with below the igneous series at a point to the west of Downhead, and render it possible that the igneous rocks may be of Silurian age, and the equivalents of those which are exposed at Tortworth.

II.—Mineralogical Society of London.

January 23rd, 1906; Professor H. A. Miers, F.R.S., President, in the chair.—Studies in Crystallisation, Sodium Nitrate, by H. A. Miers and J. Chevalier. Microscopic observations were made upon solutions of known strength contained in open tubes or sealed tubes maintained at a known temperature, or in the form of drops upon a slide, with the object of comparing the growth of crystals in metastable and labile solutions respectively. The limits of the labile state (in which the solution can crystallise spontaneously) have been fixed by previous experiments by H. A. Miers and Miss F. Isaac. If a crystal of the salt be introduced into a supersaturated solution which is not labile, the centres of growth of new crystals are on its surface, and they grow in parallel positions upon it; if it be introduced into a labile solution the new centres of growth are in its neighbourhood, and the crystals fall upon it in various positions. If it be moved about in either, a cloud of crystals is produced; but in the metastable solution this appears to be due to minute crystals which are swept from its surface. A crystal having appeared spontaneously, can continue to grow in a labile solution without producing others in its neighbourhood; but if introduced, it at once produces a cloud. This may be because the growing crystal is surrounded by a zone of metastable solution.—Geikielite and the Ferro-magnesian Titanates, by T. Crook and B. M. Jones. Geikielite occurs in association with magnesian menaccanite and common ilmenite (menaccanite) in the gem gravels of the Balangoda and Rakwana districts of Ceylon. A considerable number of analyses indicate that Geikielite varies in composition, the iron oxides ranging from 8 to 14 per cent. No specimen has hitherto been found which contains less than 8·1 per cent. of iron oxide. For this reason the formula $(Mg\,Fe)\,Ti\,O_3$ is preferable to $Mg\,Ti\,O_3$, as expressing the true composition of Geikielite. Magnesian menaccanite containing about 28 per cent. of iron oxide is very closely allied to Geikielite in all its properties, more so than to common ilmenite. The alteration products of Geikielite are similar to those of ilmenite, consisting of rutile and so-called leucoxene; the latter is a mixture of amorphous titanic acid, sphene, and limonite. It seems advisable to classify the ferro-magnesian titanates as Ilmenites and Geikielites, treating magnesian menaccanite (which has the formula $(Fe\,Mg)\,Ti\,O_3$ where $Fe : Mg = 1 : 1$) as the middle member of the series.—G. F. Herbert Smith exhibited and explained the use of a diagram for the graphical determination of the refractive index from the prism angle and the angle of minimum deviation. He also explained a simple test for ascertaining the pair of faces corresponding to any refracted image.

CORRESPONDENCE.

MACHINE-MADE IMPLEMENTS.

Sir,—Since this article appeared, I have been able, in company with Mr. C. Bird, F.G.S., of Rochester, to visit a chalk wash-mill at the Borstall Cement Works near that city.